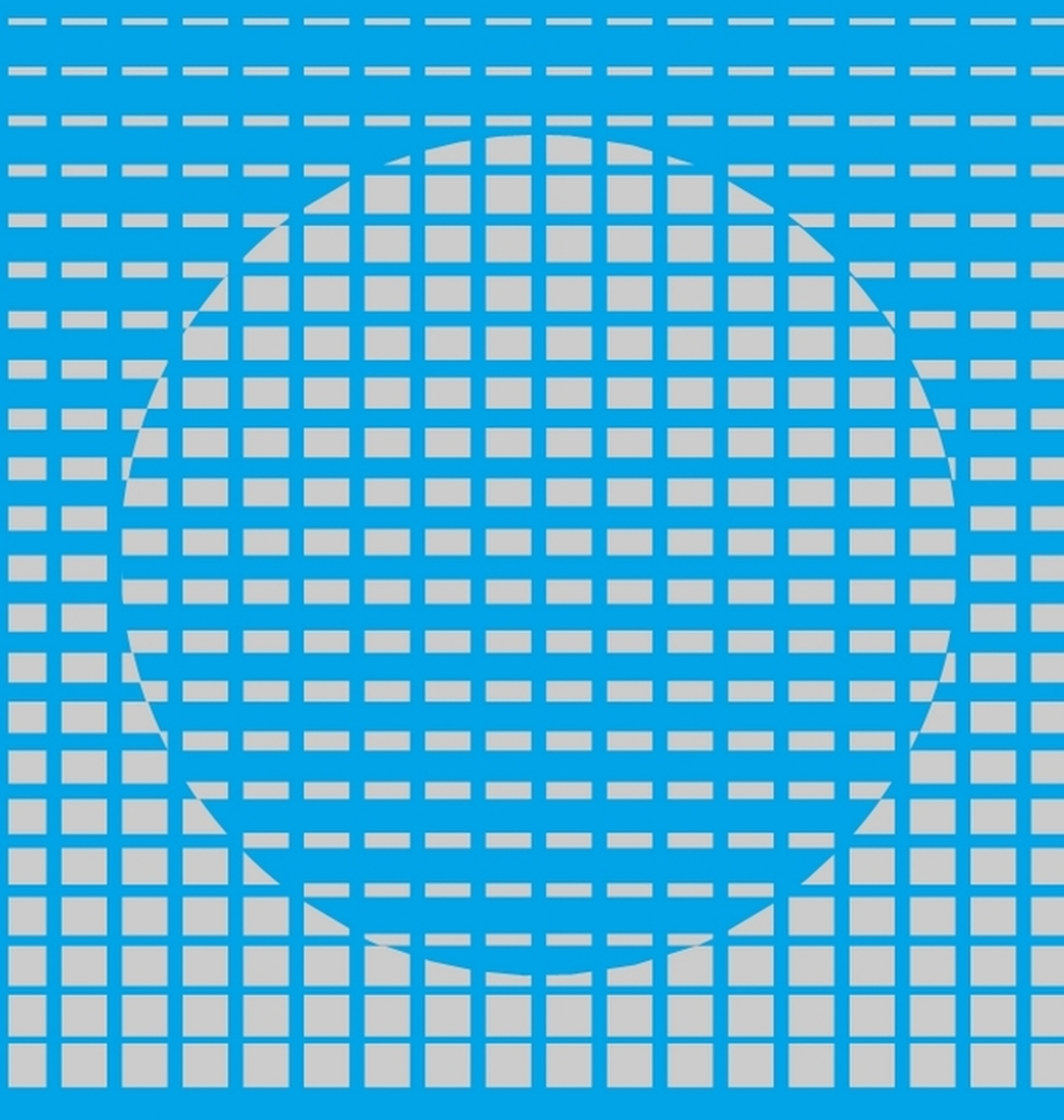
DIVERSIFYING ENVIRONMENTS THROUGH DESIGN

Taeke M. de Jong



DIVERSIFYING ENVIRONMENTS
through design

Proefschrift
ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft;
op gezag van de Rector Magnificus

Prof. Ir. K.Ch.A.M. Luyben;

voorzitter van het College voor Promoties

in het openbaar te verdedigen op

dinsdag 18 december 2012 om 10:00 uur

door

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Bouwkundig ingenieur
geboren te Utrecht

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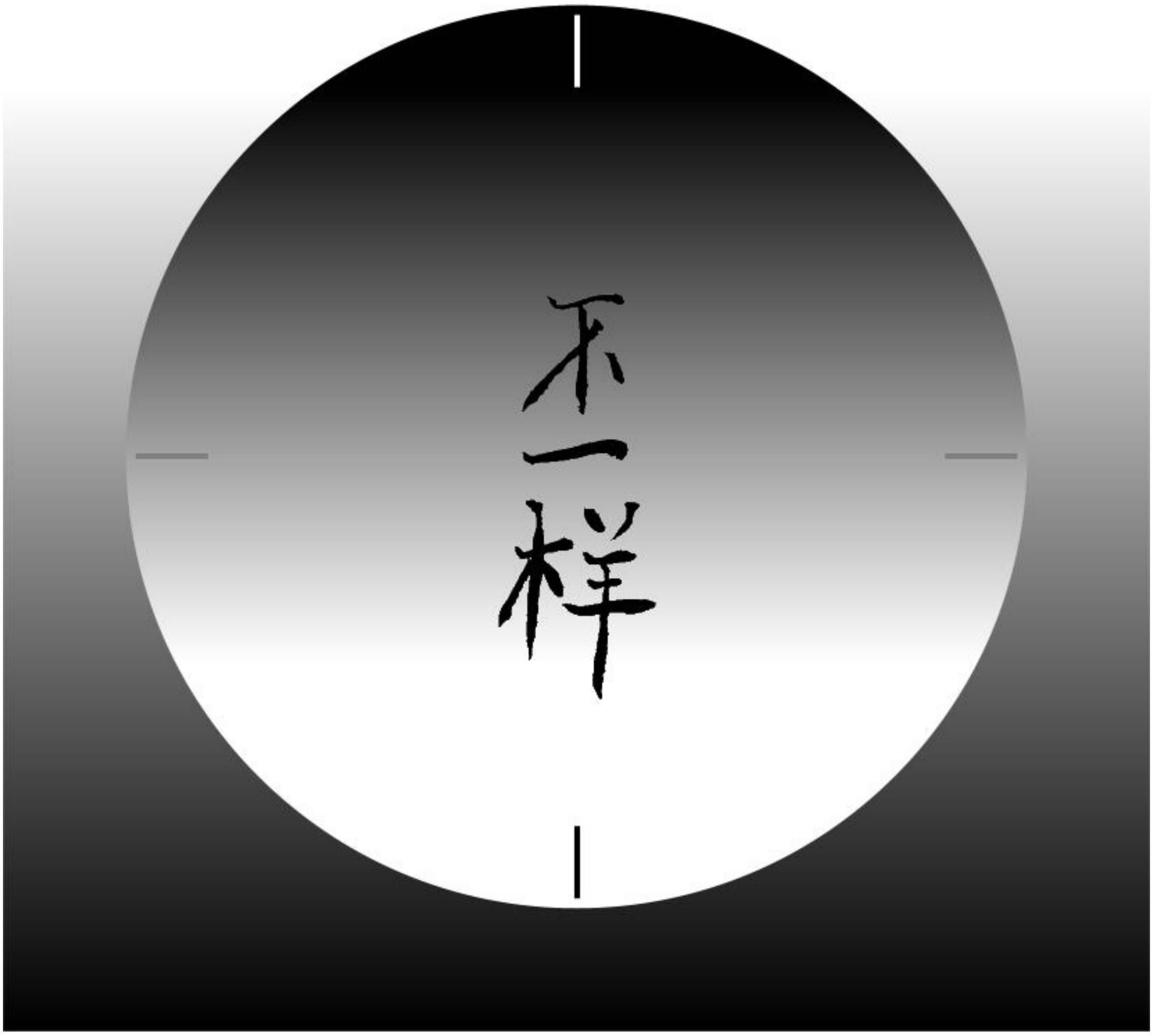
Taeke M. de Jong 2012-10-15



ISBN 978-94-6203-172-2

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Preface

Dear readers, please wait a moment, and allow me to calm down the angry young man there in the background first.

> *´Dear young man, you did a nice job in 1978, but you have made your thesis too complicated and too simple. You have produced many superfluous pages, you have invented many useless terms, and you have left many gaps. Now in 2012 I can answer many of the questions you have left unanswered, or even unquestioned.*
> *As a supervisor, to be honest, I would not accept such a thesis. Nevertheless, you showed more awareness about levels of scale than your colleagues. Your framework and table of contents are useful, sound and simple. The terms you used: content, form, structure, function and intention, are common; everybody uses them. However, you where right that they have to be elaborated more precisely and bound to scale. Many design-related theses can be written within this framework. I realised that you have written the study programme that I have followed until now. I thank you for this early insight and direction. I am probably even more scared about the increasing homogeneity of our environment (endangering biodiversity and the freedom of choice for future generations) than you are. I continued your search how to increase environmental diversity by design during the time since you wrote your Dutch thesis ('Milieudifferentiatie'). Now I have written my own thesis ('Diversifying the environment'). It deserves another defence. I have used your table of contents, but, believe me, the content itself has had to be completely re-written. You would have been fascinated and surprised, as I was, rewriting it. You did not realise in 1978 what I have since discovered. For example, a written and spoken language on its own fails to describe crucial diversities, this is where you failed. You still trusted the limited capacities of words. I thus have included some of your drawings, but I also improved the others, and I substantially extended their number and content. These drawings are crucial for this thesis, for design in general, and for a science coping with possibilities rather than extrapolating past truths into probabilities. Words name equalities. Equality is a special case of difference, not the other way around, as Chris Van Leeuwen already suggested to both of us. Our senses observe indescribable differences, unacceptably reduced when described through written word. Our designs make something different, not something equal. Designing is not merely copying or combining old things. It is not sufficient for the problems which we face this century. Designing is coping with possible futures, not only with the probable ones. Our probable futures are a tiny part of the possible ones. Looking for probability or 'truth' based equations hampers our view on the inconceivable diversity of possible worlds. It is the core of design to provide improbable possibilities.*
> *We thus need images rather than words.*
> *Dear young man, one of your possible futures has become my past. It has become largely probable now. The result is again an intermediate stage. Others may take the next step. One day they may speak to me as I did here to you. Let me report to them where we are now to enable them to proceed. After this short justification of what I did with your work, I have to leave you now. The readers are waiting.´*

Dear readers, thank you for waiting. As you may have understood, this thesis is not an attempt to find any truth or its approximations by probability as usual in empirical science.
It explores possibilities. Extrapolations of existing probabilities into the future are possible by definition, but not the other way around. What is possible is not always probable.
Probable futures even cover only a tiny part of the possible ones.

The scope of probability search

It is the task of empirical research to find probabilities, but it is the task of design to find improbable possibilities. The number of probable futures for the Earth, for its separate continents, their separate countries, towns, households, individuals, their artefacts, materials and so on, is inconceivably large. Predictions for the next moment are more certain than for the long term, but paradoxically less certain for individuals than for the Earth. Smaller uncertainties and differences become insignificant as the scope of focus shifts to a larger scale. Our window of attention does not contain anything larger or smaller than allowed by its scope (frame) and resolution (grain compared to the frame). A larger resolution would mean more detail, so smaller details would be noticed as the resolution increases, but the span of our senses and thoughts is limited. Fortunately, there is a reasonable consensus about scientific methods to make predictions (reduced imaginations of the most probable futures based on past experience). Some of these expectations frighten us. We inherently want to change them through design, and to realise less probable possibilities by action.

The scope of possibility search

There are, however, inconceivably more *im*probable, but still possible futures than there are probable ones. If our imagination is already taxed by the diversity of one history and many probable futures, then it certainly falls short imagining the diversity and multitude of *possible* futures. If we cannot *imagine* our alternatives, then we cannot consciously *choose* one of them either. We may overlook the most promising possibilities by lack of imagination, falling back on the *solutions* we know from the past. This century has other *problems*.
Every era in history has overlooked the improbable possibilities we subsequently developed into reality. They were available, but nobody could *imagine* them. Even designers are guilty of this lack of imagination. This thesis should enable to imagine more spatial possibilities, more environmental diversities. These possibilities and considerations are more necessary now than ever before. There is no hope for future generations to exist without diversity, and no chance for survival for other species. Diversity offers alternatives for survival in changing contexts. It is the strategy of life to prepare for, and find solutions to, risks.

Design methods

Unfortunately, there is not currently a method to identify improbable possibilities. However, there are widely accepted methods to identify probabilities or truth-finding. Perhaps a ‘method’ would even limit the number of possibilities you can find. This thesis thus does not describe design-methods as I had done previously.[a] There are many design methods. They are practiced, studied, recommended and applied in design education. They are mainly *aim*-directed as usual in empirical research. However, many great inventions emerged *means*-directed before they provided a target for research. Inventions often *preceded* scientific research. A properly working steam engine was invented by Watt 40 years before thermodynamics could explain its efficiency. The lightning conductor invented by Franklin motivated research on electricity. Faraday’s dynamo preceded Maxwell’s equations. Nobody knew what electricity was, nobody imagined any of its applications we now know. In the beginning its study was simply playing with electricity, without any intention of substantial use. The problem-aim-solution sequence was ineffective in identifying its *possibilities*, simply because nobody could *imagine* them. Improbable possibility search may *require* ‘solutions in search of a problem’, as it is often disparagingly formulated.

Possibilities of space

This thesis ‘aims’ to extend possibilities of spatial design that are useful in any design method. This ‘aim’, however, does not give direction to the study, as it usually does in empirical research. This study obtains direction by the *means* of spatial design rather than by its *aims*. Substantial design-means and -possibilities appear if you distinguish *orders* of possible diversity superimposed on each other: content, form, structure, function, intention.

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[a] Jong;Voordt (2002) *Ways to study and research urban, architectural and technical design.* (Delft) DUP Science

This sequence is not a method, but a consequence of expressing spatial imagination in a linear language. I cannot imagine intentions without simultaneous suppositions about functions. I cannot imagine functions without simultaneous suppositions about structures. And so on. This conditional sequence enables imagination by clarifying the preceding suppositions to be imagined first.[a] Problems and aims beforehand limit the *imaginable* set of possibilities, through hidden traditional suppositions about known functions.

Conditional thinking

If probability implies a causal sequence, then possibility implies a conditional sequence. However, in the conditional sequence applied in this study, 'intention' (containing the aims) is not the first condition (as usual in research), but the last. The possible functions of environmental diversity cannot be imagined without imagining the possible environmental diversity first. The intention or aim of environmental diversity cannot be imagined without imagining its possible functions. For empirical researchers, who silently suppose well-known functions from the past, this approach may seem bizarre: to postpone the aim of a study to the last chapters. However, in order to search for possibilities, this approach is unavoidable. Moreover, the study itself is a design. I do not know how it will be used. It does not *cause* a function; it *enables* functions. A house does not *cause* a household, it makes many households *possible*. The study of design possibilities consequently raises methodological questions about the second-order *design* of a study *about* design.
Its questions and limits, rather than its problems and aims, will be elaborated in Chapter 2.

Limits of language

Writing a thesis about *spatial* design raises substantial problems concerning the use of language. You may have observed already, that the English as it is used here betrays its Dutch background. It is not accidental. I did not always follow the formal translations of professional translators transforming my text into 'Scientific English'. Following a strictly truth-based logic, it sometimes extended my sentences and it darkened my intentions. Language is a bridge, not a barrier. And (o dear, a conjunction at the beginning of a sentence!), it develops by its use. My father's language (Frisian) developed into English, and English developed into many local kinds of English. The Latin developed into a mediaeval Scientific Language, and it was probably not even well understood by ancient Romans. For example, in many dictionaries, 'identity' is supposed to be derived from a Latin word 'identitas' meaning 'sameness' in a sense of 'identical'. However, if the police asks for your identity, it is intended to 'identify' you as *different* from any other person. Two opposite meanings of one word! When I looked in my Latin dictionary, I discovered that 'identitas' did not even exist in ancient Latin. I found 'idem(i)tidem' (repeatedly the same) instead. The etymologists apparently neglected the crucial 't' referring to itero and iterum. It refers to sameness in *time*, not in *space*. Identity thus is *difference* from the rest, *and continuity* in itself. This space-time paradox is one of the crucial problems to be unraveled in this thesis, and 'identity' hits its core.

Verbal language and drawings

My text should not be burdened by particular linguistic habits, even if it raises some prestige by its form. Extending sentences to proof your scientific standing is useless to transfer thoughts about design. The spatial idiom and syntax of design are different from *any* verbal language. It has been difficult enough to find words and sentences to express the non-verbal relations I had in mind. If they sound Dutch, than this may have the advantage to raise an awareness of hidden connotations different in different languages. I want to transfer no more connotations than strictly necessary, and sometimes to add unusual ones. Apart from this clearing faculty, a local colour may even have some added value for a thesis about environmental diversification. The English language has been a minor problem compared to

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[a] Jong (1992) *Kleine methodologie voor ontwerpend onderzoek* (Meppel) Boom
http://team.bk.tudelft.nl/Publications/1992/Jong(1992)Kleine methodologie voor ontwerpend onderzoek(Meppel)Boom.pdf

the use of verbal language as such. Two chapters were purified by professional translators. Giancarlo Mangone made the other chapters at least readable for the other native English readers. Paula van Gilst-Siliakus corrected my last failures. I am grateful for this effort, but also for the discussions with my old friend Christopher Vincent-Smith, being a native English speaker, balancing at the boundary of two languages with different connotations. His perfect understanding betrayed his background as a teacher in physics. Newton had to prune many usual connotations and even denotations of words such as force, mass, movement and acceleration before he could unveil their relations. Pruning the metaphors designers use may also unveil unexpected relations. The language of physics became mathematics. But, as I hope to make clear, even truth based logic and mathematics include suppositions a designer cannot fully share. Design goes beyond its suppositions of truth, probability and equality. In that context, a designer drawing objects that do not exist would be a liar. These objects are not true, not probable, and not equal to anything existent, but they are *possible* and *different*. Even physics has discovered the power of drawings to express structures[a]. Chemistry gradually experienced their inevitability as biology did from the beginning.

Forcing space into a time line of successive actions

A verbal language is primarily time based. The sequence of its expressions is directed in one dimension. A sentence cannot be understood backward, not to mention sideways. Its verbs represent *actions* of a subject on a target, and that may have been its primary function from prehistoric times onward. But, space cannot be forced into a time line. It cannot be described fully in terms of actions. The words used by designers betray their embarrassment to explain the 2D drawings they make. Their spatial thoughts are branched in space, but they have to prune essential side branches to fit them into a one-dimensional verbal sequence. The verbal argument does not cover the many side-roads shown in a drawing simultaneously. If a bridge is open into one direction, then it is closed in the other direction (direction-paradox). A road connects, but it separates in the direction perpendicular to its connection. The audience would 'lose the thread' of the argument, if a designer would mention every side-road jamming in direction-contradictions, even if they would support the spatially essential argument. Covering all routes and cross-sections of a drawing through speech would bore the audience. It would not even cover their visually obvious interference, their structure. A computer may show a picture on its screen in one long sentence divided in equal lines of pixels starting left-above and ending right-below, but they are related only in one direction by a simple syntax of sequence. The relations perpendicular to that direction become clear to the human observer only, and only if the lines are properly arranged. Understanding a spatial drawing requires more than understanding a sequence in time.

An escape into metaphors

Designers thus attempt to rescue their spatially branched arguments using poetic metaphors, branched into many accidental connotations. Nature is a rewarding source of metaphors. An inconceivable amount of forms and structures are available, and language provides words referring to some of them. If a building has 'wings', 'embracing' a square, then these metaphors may transfer a spatial thought in words useful to *sell* a design, but not to *make* it. Metaphors may be useful to extend your imagination in the process of design if verbalised thoughts prune your spatial imagination, but theyare not suitable to invent the possibilities of environmental diversification by design. Its exotic braches blur and limit the inconceivable diversity of *possible* contents, forms and structures you may handle in the making. May be any word is a metaphor, but the branching of metaphors differ in extension and suitability. I suppose that the metaphors 'branching' and 'pruning' as I used them above have clarified something I intended to transfer, but they expressed quite literally what happens by adding and removing connotations.

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[a] Feynman; Leighton; Sands(1963) *The Feynman lectures on physics I,II,III* (Menlo Park, California 1966, 1977) Addison-Wesley Publishing Company

An inextricable jungle

The words used in architectural discourses between designers and their critics do not add the connotations suitable in the language game I would like to play: the game of possibility. Forty[a] summarises some key words in the language game of the architectural discourse: character, context, design, flexibility, form, formal, function, history, memory, nature, order, simple, space, structure, transparency, truth, type, user. In his essays on any of these key words he cites famous architects and critics and he refers to crucial texts on architecture. They often speak in metaphors with something for everyone. It is striking how far the use of these words in this discipline deviate from the same words used in any other discipline. Even 'form', 'structure' and 'function' are used as metaphors with so many branches, that they have become meaningless. Each tree has become a jungle in itself. Changing words such as 'structure' and 'function' into 'system' and 'affordance' will not prevent the same jungle. They have to be pruned, not by language but initially by distinguishing direction and scale. Language does not have a North-arrow and a scale as drawings do. Time is its direction and its categories very often hide an implicit level of scale (and consequently a resolution). Conclusions about the form, the structure and the function of a chair are implicitly used in the next sentence to argue how to design a town. This may be useful as a metaphor, but concealing the scale of an argument causes serious mistakes. These confusions are so serious, that I distrust any text containing scale-sensitive categories without an explicit specification of their scale (unless it is absolutely clear by its context). It clarifies the relatively limited number of citations in this thesis.

The direction may be a lesser problem, because it is often given in a sentence with a subject, a verb and an object or target: 'I fell a tree', 'I go home'. If the action is represented by a verb, preceded by the actor and followed by the result, then it is a *function* from the actor into the result: result = f(actor). But, it contains a causal supposition. The direction may be projected in a temporal sequence, but it still raises confusions talking about spatial objects not supposing any *specific* direction or action. Design supposes conditions. A cause is a condition for something to happen, but a condition is not always a cause.

Direction

Suppose you agree with me that a ball is always convex, and we find one large enough to enter. You enter the ball and you conclude that we have made a mistake. "A ball is concave!" you shout to me from the inside. I disagree, and we have an argument at the entrance. We call a judge to decide whom of us is right. The judge is a wise man, and a well-respected authority in this field. After some minutes with a frown he has made his decision. "Perhaps", he says, "you are both right". He waits until this deep thought has calmed us down to be prepared for his final conclusion: "A ball is *undulating*: now convex, then concave". He walks away with a smile, leaving us in embarrassment. His 'now and then' solution is according to our experience in time, but 'undulating' does not agree with what both of us have seen. We decide to distrust our eyes and to accept the verbal wisdom of such a well-known authority. Science often has been advanced before by distrusting personal experience in favour of a verbal expression. In this case, however, it has moved us further away from reality than each of the verbally contradicting experiences did before. This does not only happen discussing a ball. It also happens discussing more abstract concepts such as 'function'. A dwelling has an inward function for its neighbourhood, but it has a different outward function for its residents. This direction-sensitivity is confusing if you do not recognise the substantial difference between both opposite or at least different concepts of inward or outward 'function'. And, it happens at any level of scale again.

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[a] Forty(2000)*Words and Buildings A Vocabulary of Modern Architecture*(London)Thames & Hudson

Scale

Suppose, you walk through a street with buildings, and they are all different from each other. You turn the corner into the next street, also with buildings, each different from the other ones, and so on. After 20 minutes walking, you may conclude that every street is the same. None of them has a recognisable identity. The neighbourhood as a whole is homogeneous. What happened? Walking 100m you saw diversity, but after 300m you saw a homogeneous mixture. Diversity$_{100m}$ everywhere has caused a kind of homogeneity$_{300m}$. The buildings are different, but the streets would have been more different if their buildings would have had something *in common* per street. *What* they have in common in one street should of course be different from what they have in common in the other streets. Some equalities$_{100m}$ would enable differences$_{300m}$, if at least these *equalities are different*. The statement 'equalities are different' sounds as a contradiction if you do not distinguish levels of scale. I call this phenomenon 'scale paradox'. It is a spatial equivalent of Russel's paradox, of which 'I lie' is an example (if I lie I speak the truth, but if I speak the truth, then I lie). The solution is to distinguish the level of the expression from a meta-level *about* the expression. If you tell a lie and *after* telling that lie you would say 'I lied', then you would speak the truth *about* the lie. If the scale paradox applies to difference in general, it applies to any difference. The diversity of functions such as sleeping, cooking and cleaning afforded at home$_{10m}$, does not *diversify* the street, but it is *repeated* in the street$_{100m}$. To diversify functions in the street$_{100m}$ you may use other variables such as plantation, pavement and street furniture. Any level of scale may have its own most suitable variables to diversify the environment. These variables with values are eventually used as a legend of a drawing. Environmental variables, their values - eventually used as legend units - are the 'content' of environmental diversity.

Content

Any drawing has a legend. A legend (Latin for 'what has to be read') is the 'vocabulary' of the drawing. Some legend units are so generally used, that they are not specified in a separate legend. A line may indicate self-evidently a separation or a connection; red may indicate 'built-up', and green 'greenery'. The number of legend units in a drawing may vary between 3 and 80.[a] The vocabulary of a text is mainly much larger, but in a drawing the legend has three advantages not immediately present in a text. Any legend unit in a drawing directly represents a quantity, a general form and separate shapes. The quantity is represented by the length or surface it covers in the drawing, specified by every several length or surface. For example, the capacity of an urban plan can be checked counting the surface covered by the legend unit 'built-up'. The form is represented by the dispersion of a set of singular surfaces from one or more legend units in the drawing. You could call it the 'inward form'. The 'outward form', the shape, is readable from any coloured or circumscribed surface in a drawing separately. In this thesis, a primary question is: which legend units are possible at all? To answer this question, a category of legend units is named as a 'variable'. Built-up areas may have different building heights represented by different shades of red. These different shades, e.g. representing buildings of 0, 1, 2 …10 stories high are the possible values of the variable 'built-up'. The values a variable can contain are a set of legend units. I found approximately 150 design variables that could be applied at 6 different levels of scale, on average. If they have a different meaning at every level of scale, producing a different kind of diversity, then there are 900 variables. These variables count 3 values, on average. The possible vocabulary of spatial design then would count approximately 2700 'words', or legend units, to be dispersed in space.

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[a] Jong;Witberg(1993) *Stromend Stadsgewest, Legenda-analyse* **IN** Klaasen, I.T.; Witberg, M. *Het Stromende Stadsgewest derde Eo Wijers prijsvraag plananalyse* (Delft) Publicatiebureau Bouwkunde Delft http://team.bk.tudelft.nl/Publications/1993/legendaanalyse.doc

Form
If V values or legend units are dispersed at L locations in a drawing, then the number of possible alternatives is V^L. If you choose either red or green for every m^2 on a 20 x 20m = $400m^2$ lot, then the number of possible forms (2^{400}) is already larger than the number of atoms in the universe (i.e. a combinatoric explosion). A small part may be useful as proper designs, but that number will be still inconceivably large. A designer cannot handle such a multitude, evaluating their potential use to optimise the form. And, it will be even larger if you choose more than two legend units. Anyhow, the content (legend) is obviously not the only factor to determine environmental diversity by design. The same content can appear in an inconceivable multitude of forms. Apart from a chapter about diversity of content, there should be a chapter about the diversity of form. To cope with its possible multitude, I looked for a second order variable of 'form' starting with two legend units to be dispersed (to produce a 'form' and a background 'counter-form'). What could be its absolute value, the zero-point of form? I chose two extremes: total accumulation and total dispersion of a legend-unit. Any form is positioned somewhere in between, but which of both should be the zero-point from where you can measure its deviation? I chose total accumulation as a zero-point, always approaching a circle or a globe by closest packing. Any deviation from a circular shape is more dispersed and dispersion has no limit in an expanding universe. Total accumulation may be a black hole causing a problem for physics as its 'dark knowledge', but for us, a '0' perfectly represents the zero-point of form.
I did not manage to find a method to measure the deviations, but I made at least a start. Something else bothered me more: how to make the step from 'form' into possible 'function'. This thesis limits 'function' to workings for people. 'Function' introduces time again. Stability is a hidden supposition in the working of many things potentially useful for people. A completely unstable form mainly does not 'work'. A house dispersing as a cloud does not work, an evaporating computer or a liquidising hammer does not work either. What, then, keeps a form in good shape or condition? A set of connections and separations in different directions at different levels of scale stabilise a form. At a molecular level, they may appear as attracting and repulsing forces. At the level of a building they appear as stress- and pressure-resisting components, such as cables and columns, or as components resisting, directing or selectively allowing movements such as walls, doors and windows. At the level of a town, they may appear as an infrastructure of roads, cables, pipes and dikes.

Structure
In this thesis 'structure' is defined as 'a set of connections and separations stabilising a form'. The usual definition 'the way parts form a whole' applies to any composition with components still not necessarily connected or separated to stabilise them. The real structure may be used as a metaphor to explain the perception of a composition as 'coherent' (harmonious), 'connecting' (relating) some components, while others are 'separated' (contrasting). But, that kind of connotation should be pruned if you want to position structure between form and function. It is even worse if 'structure' is confused with 'order' as a kind of regularity observed in a composition, a form with components arranged in a repetitive *pattern*. You may then suspect a 'structure' keeping similar components in their place, but it is often the result of a process obeying the laws of entropy, *dis*order at an other level of scale. The closest packing of oranges in a box forced by gravity or the regular pattern of soap bubbles forced by dispersing and balancing surface tensions causes beautifully ordered hexagonal patterns, but there are no connections and separations stabilising this pattern. It is the result of a process, far from equilibrium. Shake a box of cigars in a chaotic position and they will order themselves in such a way that you can close the box. 'Self-organisation' has nothing to do with organisation, the diversification of organs purposefully specialised and accordingly separated and selectively connected in an organism or organisation. Membranes and fibres *between* these organs take their own place as connections and separations. Structura is Latin for brickwork: the separating bricks are connected by layers of cement, taking their own space to stabilise the bricks.

Functional diversification
Discussions concerning the 'meaning' of forms reveal that, even if I had succeeded in providing an exhaustive description of morphological and structural diversification (which I did not), this description would nonetheless fail to explain how the same structure with the same content and form may have different meanings and uses: *functions*. This made it necessary to write a fourth section (Chapter 6) about 'functional diversification'. The same thing (having the same content, form and structure) may have different functions for people, animals, plants or constructions. A wooden beam may have one function (working) in a construction, a different function for fungi, insects or birds, or it could be used as fuel by people. Functions for people, however, are different from those for constructions, plants and animals. Moreover, the term 'function' itself is ambiguous. It was necessary to explain this properly before I could arrive at the functional diversification relevant for urban design in Chapter 6. Even within this restriction, however, there are countless 'functions'.
How can we understand functional diversification if we can distinguish so many functions?

Functions for humans
Chapter 6 is restricted to functions for humans and society within an urban environment. The well-known distinction of four urban functions (i.e. residential, employment, recreation and traffic) is apparently based on a supposed mutual nuisance. The Congrès International d'Architecture Moderne (CIAM) asserted the necessity of spatial separation between these functions in order to avoid nuisance. This approach, however, results in separations that exceed the reach of the nuisance. Other distinctions (e.g. administrative, cultural and economic functions) can be subdivided more systematically. In 1978, one city in the Netherlands (The Hague) had a primarily governmental function, while others (e.g. Amsterdam and Rotterdam) primarily served cultural or economic functions.
The latter distinction appeared useful for describing the process of functional diversification. Mediaeval towns also had administrative (castles, palaces), cultural (churches, cloisters, schools) and economic functions (markets, shops, dwellings, small traditional trade businesses), albeit at a smaller level of scale. At that time, administrative functions could be further diversified into functions for legislative, legal and executive facilities, reflected within the city through town halls, courts of law, governmental services, police stations, prisons, barracks and military training grounds. Cultural functions could be further diversified into the categories of religion or ideology, art and science, childrearing and education, reflected within the city through churches, monuments, signs, museums, institutes, libraries, socio-cultural facilities and schools. Economic functions could be further diversified into production, exchange and consumption, reflected within the city through firms, banks, offices, distribution points, shops, infrastructure, living, health service and recreation. Chapter 6 recognises this approach as 'inward' and its adds a complementary 'outward' approach.

Difference
Empirical science collects facts to find *equalities* called generalised 'knowledge'. Design applies many existent components and this requires generalised knowledge. But the core of design is to make non-existent objects, *different* from what exists. How to make them different from what we know or expect as probable? The number of possibilities is inconceivable. A design cannot be a conscious choice between unimaginably many possibilities. If you are not even aware of them, then you are inclined to choose traditional solutions. But, the problems we face are not traditional. We have to make a difference. The world population doubles twice in a life time; the environment changes; the context changes. The diversity of possible futures is larger than history, larger than the sum of all probable futures together and consequently larger than anyone can imagine. We have to cope with this diversity, but we can't. We have to cope with difference, but we are educated in equality, equations and generalisations. 'Different' is often concerned as the opposite of 'equal', but that is a mistake. You cannot recognise a difference if things are equal, but you can

recognise an equality if things are different. Equality is a special case of difference. An object can be more or less different from a second object, but not more or less equal. If objects differ less than the least difference you can observe or imagine, then you *call* them equal. Equality is the zero-point of difference. It can be approached, but not reached, otherwise the objects you compare should be the same thing. And, the expressions 'A = A' or 'A = not A' only make sense if A can change during the reading passing the '=' sign. In that case they express continuity or change. Change thus is also a special case of difference. It is the difference between what you see and what you remember. Thus, continuity is consequently the zero-point of change. It can be approached, but not reached, because a memory is something else than an actual impression. According to Plato, Herakleitos would have said: "Anything changes". But I am inclined to say: "Anything differs". Without difference nothing can be observed or realised; without the concept of difference nothing can be chosen or thought. Distinction is the very beginning of imagination and thought. If equality is a special case of difference, if probability is a special case of possibility, then empirical science may be a special case of design. In the field of empirical science and education, this awareness increases, but in the field of design science and education, it surprisingly decreases. You cannot learn to create improbable possibilities by probability calculations. Evidence-based design is a dead-end street. It narrows down your capacity to imagine possibilities. This thesis aims to widen it.

Sets

A category or set supposes an outward *difference* to imagine the inward *equality* of its elements. But, the definition of a set according to Cantor[a] does not refer to this difference. Instead, it requires the definition of a common characteristic of its elements to assure some inward equality. The definition of this characteristic, however, necessarily uses words. Words themselves are categories or sets. To define subsequently these words, you will need other words. And so on. But, to refer to the outward difference instead, would require one to point out every object that is outside the set separately, using the word 'not'. Distinction is the very beginning of a vocabulary, but the distinction itself does not have a name. The *objects* that should be distinguished have names. Verbal language requires a subject and an object to explain the difference: "This differs from that". The difference *between* this and that is nota bene represented by a verb! A drawing does not have to translate a spatial difference into a change. A boundary between red and green self-evidently explains the difference. If you ask somebody "Which colour is the boundary?", then there is no answer. Designers *start* drawing boundaries, even if they still do not have any idea what exists at both edges. They study *possibilities*. It obviously cannot be done sufficiently by language. There are many objects, but there are inconceivably much more *differences* between objects. To study possibility requires the designer to cope with that diversity, and that is what we unlearned at school. This thesis aims to relearn it.

Kinds of difference

There is still a paradox I cannot solve: the expression 'kinds of difference'. I need it in this thesis, but it is a contradiction. There are different differences: differences in content, form, structure, function or intention. Content is a primary kind of difference. Difference of form is a second order of difference: the difference of dispersions in space of some content. Let me use Δ for 'difference of' to be not too boring. Δstructure is a third order of difference: the Δsets of connections and separations stabilising the form. Δfunction is a fourth order of difference: the Δuses of structures by humans. Δintention is the last order of difference: the Δbalances between functional needs and possibilities. Using the concept 'kind of differences' supposes an 'equality of differences'. What, then is the difference silently supposed *between* these sets of difference? I do not know. I simply trust the boundaries set by the young man.

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[a] Cantor(1895)Beiträge zur Begründung der transfiniten Mengenlehre(Mathematische Annalen)1100 46 4 p481-512 Springer http://gdz.sub.uni-goettingen.de/dms/load/img/?PPN=PPN235181684_0046&DMDID=DMDLOG_0044

Reading this thesis

The chapters of this thesis are written in a conditional sequence. The next supposes the previous, but you may read them separately. For practical purposes, you may jump to Chapter 3 on page 109, skipping the social and scientific justifications of Chapters 1 and 2. Every chapter is subdivided into sections and short paragraphs, with a title representing its content. It enables you to jump into paragraphs of interest. The thesis ends with an extensive index of terms, concepts and names, composed by syntactic key words (explained on page 274 and onwards). Spaces are omitted if they are not necessary.
If the North direction of a map or plan is not indicated by 'N', then the top of the image is the North direction. The scale of maps and plans is indicated by a circle with a radius R (not a diameter) given in the text accompanying the figure. In other parts of the text, the scale factor 'R' is defined as the 'nominal radius' of the area to be studied. Its value can be one of the set {1, 3, 10m….300, 10 000km} indicating the order of size of a length, a surface or a volume. The values are 'nominal', because 'R = 3m' may be interpreted as ranging between 1 and 10m (see *Fig. 17* on page 52). 'r' indicates a similar nominal radius of a *component* or the *smallest grain*. In a similar way P and M are used for polarities and mesh-widths in networks. If '$\Downarrow$' is used, then 'y $\Downarrow$ x' means 'y supposes x' or 'x is a practical condition for the possibility of y'. 'Condition', thus, is not used in a logical, but in a practical sense.

References

References are given both as footnotes at the referring page and in the list of background literature on page 311. The in-text indicators of the footnotes are given at the end of a sentence if they concern the sentence as a whole and within the sentence if they concern a part of the sentence. Within the first pair of brackets of a reference, the year of the first publication is given. The second pair of brackets contains the place of the publishing and eventually a year of publication if the reference refers to a later edition, or it contains the title of a journal. If the second pair of brackets contains the title of a journal, then a four digit number after the last bracket indicates the month and the day of publication, eventually followed by a space, the volume, the issue and the first page number divided by spaces. This format enables computerised recognition of the reference data.

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1 Three language games

1.1 Modes of reason

Action, reflection, decision

The world of our experience has been divided into modes of action, reflection and decision. You cannot easily switch from one into the other. Different language games are now required: different distinctions, a different logic, a different kind of communication. Despite the fundamental and necessary unity of the individual, you have unquestioningly accepted that these tasks are divided in time, in space and even between people. There is a time to act, a time to reflect and a time to decide. There are places of action, reflection and decision-making. There are artisans, scholars and managers. And, these modes are divided at many levels of scale. There are workshops, instruction rooms and decision rooms. There are factories, schools and offices. Any mediaeval town had a market place, a church and a town hall. Any contemporary conurbation has areas for industry and shops, for culture and schools, for the offices of government and management.[a]

Lost awareness

Even though you can know, choose and realise more than ever before, you must wait until there is enough information, until it is decided, until the finances are guaranteed and until it is made. The intermediate time is filled up with specialised work in other projects for your employer or clients, in order to earn the money for your own projects, your household, your leisure or your enterprise. Money does not acquire value until it is spent in the realisation of your own projects; it is essentially a delay of payment. Its anonymous exchange dims your awareness of the other modes - and *their* further task divisions - assumed and supplied in anything you buy. You do not *practice* them, you do not *know* them and you did not *choose* any of them. You once chose your own specialisation and network.

Part in a sequence of actions

This is a consequence the unique human ability to oversee a range of actions only the first of which can be done immediately[b] and only the last will satisfy.
You have accepted the fact that once you have chosen, the action and the knowledge will be largely the territory of specialised other people or of self-evident facilities remaining from the past. You take them for granted. You have accepted that the situation in which you act is not a situation in which you can reflect or choose; it is either a situation that has been reflected and chosen for you or one upon which you have reflected and for which you have chosen in a remote past.

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[a] This ‘trias urbanica’ has been recognised by such authors as Brugmans and Peters, George, Jakubowski:
Brugmans; Peters(1910) *Oud-Nederlandse steden 1 en 2* (Leiden) Sijthoff
http://team.bk.tudelft.nl/Publications/2012/Literatuur/Brugmans(1911)1.pdf
http://team.bk.tudelft.nl/Publications/2012/Literatuur/Brugmans(1911)2.pdf
George(1966) *Geografie van de grootstad, het probleem van de moderne urbanisatie* (Utrecht / Antwerpen) Het Spectrum
Jakubowski(1975) *Basis en bovenbouw* (Nijmegen) Socialistiese Uitgeverij Nijmegen
[b] Harrison; Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press

Communication between modes

If it is important to restore the unity of these modes, it is also important to recognise their separation. It is a crucial ambition of this study to restore the communication between technology, science and policy, as well as between design, research and decision-making. This distinction forces itself upon us in the failure of the communication between science and technology (i.e. knowing existing things and making new ones), understanding and artisanship. It forces itself upon us, when expertise and the power of decision, science and policy, expertise and management, go their separate ways, with all of the adverse or even fatal effects associated with such a situation. If this communication fails, decision-makers may choose impossible or past futures, designers may invent undesirable objects and scholars may discover useless facts or truisms.

Language games

To begin, it is important to understand the distinction between these modes and their different terminology. You cannot restore their unity before their distinction is clear. You cannot achieve this aim before the problem is understood. This problem emerges in any project, even if it is not recognised by the participants. Any project contains a projection into some future. The problem is thus that these three modes are oriented towards different futures. They acquire different perspectives in different social sectors. They become divided over different types of activities and professions, requiring different modes of thinking and communication. This reduces your reality in different categories (see *Fig. 1*). Wittgenstein referred to context-sensitive ways of talking and writing as 'language games'[a]. These games may use the same terms to refer to different things or different names for the same things. Their vocabulary and meaning are dependent upon their context.

Language games	**Being able**	**Reflecting**	**Choosing**
Futures	possible	probable	desirable
Sectors	technique	science	management
Activities	design	research	policy
Modes	conditional	causal	normative
Reductions as to			
character	legend	variables	agenda
location or time	tolerances	relations	appointments

Fig. 1 Three language games to be covered in any project

Probable, possible and desirable futures

If you accept that any *probable* future is *possible* by definition, but not the reverse, then the probable futures are a subset of possible futures (see *Fig. 2*). If so, there should also be *improbable* possibilities. Because they are not probable, you cannot expect or predict them in a *causal* way. You must *design* such possibilities by shaping their technical *conditions*. The mode of conditional thinking differs from the mode of expecting the effects of causes (see *Fig. 3*). A house does not *cause* a household; it makes many households *possible*. Deciding whether you also *want* these households, is yet a different mode. Many of the desirable futures are not possible. Forget them. Other desirable futures may be probable. Do not take action. You can expect them to happen without action. Take action only if there are probable futures that you do not want (problems) or if there are improbable possibilities that you would like instead (Aims, see *Fig. 2*).

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[a] Wittgenstein, L. (1953) *Philosophical Investigations* (Malden, Oxford, Victoria 2001) Blackwell Publishers

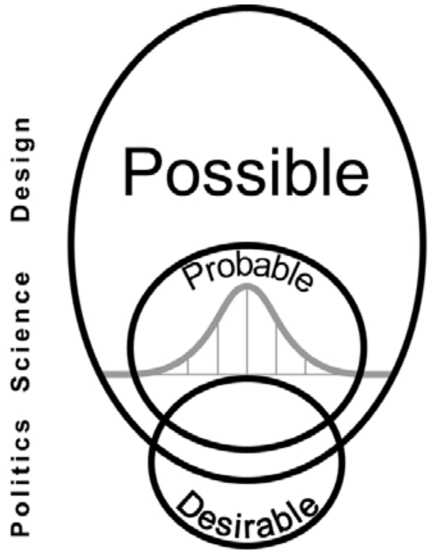

Fig. 2 Possible, probable, and desirable futures

Fields of problems and aims

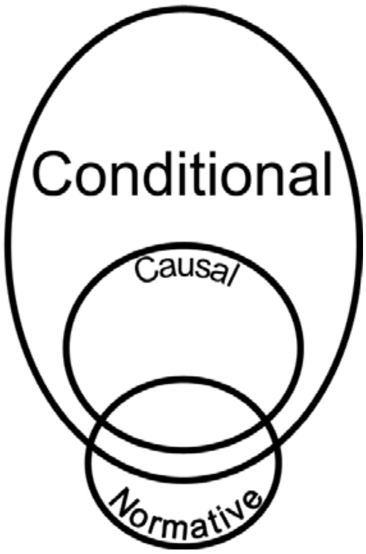

Fig. 3 Modes of reason

Science and humanities as a design

If you associate a conditional way of thinking with design and causation with science and humanities (see *Fig. 3*), you may conclude that any cause is a condition for something to happen, but not the other way around. Conditions do not *cause* events; they only make them *possible*. You may even draw a conclusion that empirical researchers are not very likely to accept. You may conclude that science and the humanities constitute a design in and of themselves, and not the other way around. If they are a subset of design, then design cannot be fully covered by an empirical language. If this is true how should you cope with the improbable possibilities that remain for design in a scholarly way? Which language and logic are needed? If you are able to develop such a logic of technical conditions, it should also be valid for any causation. Causes *suppose* conditions. This may be the key to a common vocabulary and language. If you are not interested in impossible desirable futures, then it could also be a vocabulary and language suitable for politics and decision-making.

Priorities

My first priority is to be understandable and useful for spatial design and technology. The forum for this first priority is the community of spatial designers. They do not search for empirical *probabilities* or even *truths*, but for a larger set of *possibilities*. If a design were to be only probable, it would be a prediction. If it is to be a design, it must also include improbable possibilities, which may become true by realisation. Only after realisation can they allow empirical evaluation of their observed impacts. Such evaluation can suggest probable effects for future designs in other contexts, but this is not the core of design. It is part of its business as probable futures are a part of what is possible (see *Fig. 2*).

The second priority in this study is to be understandable and useful for empirical research and theoretical study in science and the humanities. These fields search for *probabilities,* or even *truths*. This thesis, however, contains very few empirical data. It is intended as an exploration of the *kind* of data that designers continue to need from science and the humanities. It attempts to translate some of these questions into a design language that may be more understandable to researchers. A design is not a prediction. It is neither true or false. It is even not probable. It is a possibility and a proposal that may be desirable.

The third priority is to be understandable and useful for policy and decision-making, for government and management. These areas look for what is *desirable* at different levels of scale. They decide about designs as proposals. They must balance what is probable, but not desirable (problems). They must be able to imagine what is not probable, but desirable and possible (aims). Let me first elaborate these modes of reason separately in more detail.

1.2 Spatial design and technology

The relevance of spatial design

The aspiration to be useful in spatial design (including technology) raises the underlying question of why spatial design itself may be useful for humanity and for society. Many nice utilities, buildings and towns have been built without the preparation of professional designs beforehand, separated from their realisation. A professional spatial design thus supposes to add quality (including new possibilities). This supposition justifies its profession and its education. It leads to the question of what 'quality' means within the context of spatial design.

Spatial quality

One of the oldest known texts on architecture was written in Latin by Vitruvius some decades before Christ. In the second paragraph of Chapter 3, in the first book, the most cited combination of words to date appears almost innocently. It is a simple distinction of architectural qualities: firmitas, utilitas, venustas (strength, utility and grace[a]). I translated this well-known distinction into a form intended to be useful at levels of scale exceeding those of buildings upon the request of a land development company (Heidemij) at the end of the 20th century. My translation reads: 'Value for the future (durability, sustainability), value for use and value of the image'. This description of quality appeared in Dutch governmental plans and it was frequently cited. As did its predecessor from 1978 this thesis contains an earlier formulation as structural, functional and morphological quality at any level of scale. You may recognise this formulation in the distinctions contained in Chapters 5, 6 and 4. In these chapters, however, the sequence of form (4), structure (5) and function (6) is conditional. Studying their *diversification* (the simultaneous process of morphological, structural and functional diversification) made it necessary to change their sequence in a conditional way. Their meaning shifted slightly in the process. Let me first concentrate on the sequence and then on their diversification.

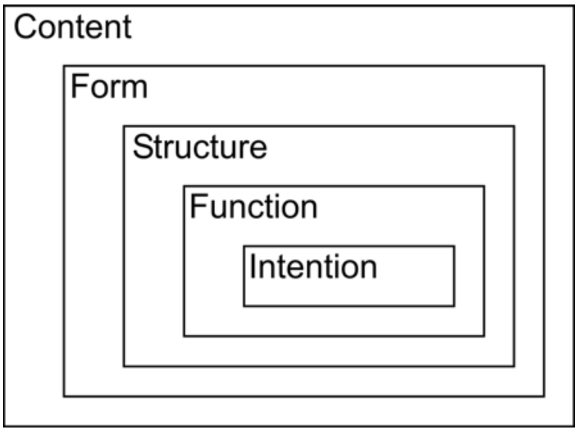

Fig. 4 Intention $\Downarrow$function $\Downarrow$structure $\Downarrow$form $\Downarrow$content

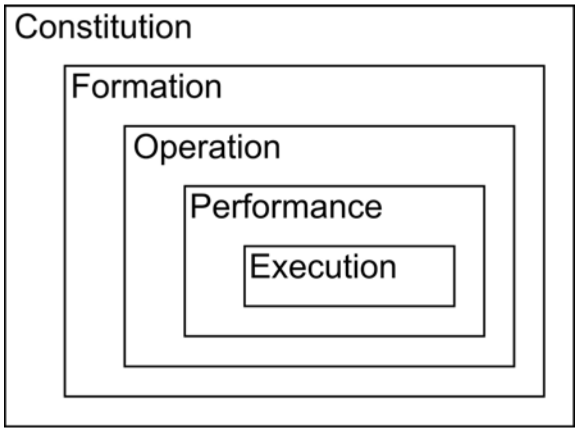

Fig. 5 Dynamic equivalents

A conditional sequence

The sequence of form, structure and function is not accidental. It is conditional within the mode of possibility. The latter *supposes* (as indicated by $\Downarrow$) the former (see *Fig. 4*[b]) if you

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[a] Vitruvius(27 B.C.) *De Architectura* (Cambridge Massachusetts 1983)Harvard University Press Loeb Classical Library series, Book I, Chapter III, Latin on page 34, with an English translation by Granger on page 35. Granger translates 'firmitas, utilitas, venustas' by 'strength, utility, grace'. On http://www.gutenberg.org/files/20239/20239-h/29239-h.htm Morgan translates them with 'durability, convenience, and beauty'.

[b] In *Fig. 4* and *Fig. 5* these categories are shown as Venn-diagrams. Instead of indicating subsets as a part of ($\subset$) sets with *true* conclusions, however, they represent *possibilities* that suppose ($\Downarrow$) *technical* conditions. The diagrams are best understood as

accept a slight shift of meaning from the usual discussion of form and structure.
Any function (i.e. working) supposes a structure (i.e. a set of connections and separations). Any structure supposes a form (i.e. a dispersion in space). None of these aspects *causes* the latter making it *probable. Instead,* they *condition* the latter making it *possible*. Any structure supposes a form to be *operational,* and any function supposes a structure to be able to *perform* that function[a] (see *Fig. 5*). A function without a sufficiently stabilising structure may become useless in its first performance. Many utensils can be used only once, as their connections or separations are broken by that use. In order to be suitable for more frequent re-use, they require more durable connections and separations - they require more value for the future, more structure.

Structure ⇓ form

In its turn, a structure without a form does not have separate components to be connected. Even the words ‘separation’ and ‘connection’ do not have any imaginable meaning if they cannot be related to objects at different locations (a dispersion in space). ‘Form’ is supposed in any concept of ‘structure’ (i.e. the way *separate* components are *connected* together or conversely, the way *connected* components are *separated*, e.g. by a wall). Where components are composed into a composition (i.e. ‘formation’) they must suppose a form before we can recognise the difference between and the direction of their connections and separations (structure). It is for this reason that a chapter on morphological diversification should precede a chapter on structural diversification.

Structure and direction

Separation and connection require a spatial direction in order to determine their operation, even if that direction is variable. Separations perpendicular to connections are essential in any operation. For example, an electric wire requires isolation perpendicular to the direction of the afforded connection. If ‘perpendicular’ has no meaning, how are we to determine the operation of separation and connection?
This distinction between form and structure produces simple and operational definitions: dispersion in space (form) and the set of connections and separations (structure) stabilising the form.

Form, formation, composition

Function and structure do have dynamic equivalents (see *Fig. 5*): performance and operation. In this context the dynamic equivalent of ‘form’ is called ‘formation’, although ‘composition’ would fit as well. In the discussion below, ‘composition’ is used in this sense if demanded by the context. However, ‘composition’ has a dual meaning. You can ‘compose’ a form in the way painters or even musicians do (i.e. a distribution of components in space or time), but you can also ‘compose’ a content (as with the colours that painters choose before they distribute them on the canvas or the notes that musicians choose to distribute them over time in order to achieve a composition).

Form ⇓ content

Even a form supposes something that *takes* that form. There must be some content or matter *to have* that dispersion in space (*Fig. 4*). In designs this can be recognised in the form of a legend and its legend units (which are often implicit).

Intention ⇓ function ⇓ structure

At the other end of the range, the same function and its performance may be appreciated differently by different people in different contexts, each with specific desirabilities. Although function may suppose a structure, it *is* subsequently supposed in any human intention.

3D, imagining a third dimension.

[a] Tzonis, A. (1992) *Huts Ships and Bottleracks Design by Analogy for Architects* **IN** Cross, N.; Dorst, K.; Roozenburg, N. *Research in design thinking* (Delft) Faculty of Industrial Design Delft University of Technology the Netherlands Proceedings of a workshop meeting. Tzonis uses the terms ‘operation’ and ‘performance’ to refer to the action of structure and function.

Directions and dimensions
If you wish to study environmental diversification, you must study the diversity of contents, forms, structures, functions and intentions, as well as their development within that sequence (*Fig. 4*). Any of these aspects can be different in different directions (x, y, z), as well as within the fourth dimension of time (t). In time, their dynamic equivalents merely receive a different name (*Fig. 5*).

Quality is a function
The Vitruvian ‘grace’ thus becomes primarily a *function* for people, just as with any other ‘utility’. It is apparently an important function, as it determines a substantial part of the price paid for buildings. But, if it is a function, then it must suppose something that performs that function. This should be a stripped concept of ‘form’, possibly stabilised by a structure. A form either pleases people or does not. Form is thus something other than its appreciation. Whatever ‘form’ may be without such a ‘meaning’, it precedes its function for people. Moreover, the same form can acquire different meanings for different people. Such functional diversification does not affect the form. This is a second argument with which to distinguish ‘form’ from any meaning *of* the form. For this reason, the hidden supposition of ‘grace’ (form) is separated and advanced in this analysis.

Visual quality ⇓ limited morphological diversity
The connection of form, structure and function to diversity and diversification is also not accidental. There is a relationship between visual quality and diversity, as noted by Birkhoff[a] and Bense[b]. The morphological quality of endless repetition is low. It is boring, and it looks cheap - but, the visual quality of excessive diversity is low as well. It is chaotic. Sensory quality falls somewhere in between, varying between surprise (by differences) and recognition (of equalities, see *Fig. 6*). The boundaries between excessive repetition and proper recognition and between acceptable surprise and chaos are present in any compositional work of art, be it painting, music or even culinary art.

Visual tolerance
This may be a special case of the well-known curve of ecological tolerance. For example, the chance of survival for plants on land depends upon the availability of water. An insufficient supply of water results in a small chance of survival just as an overabundance of water does. Every species chooses the right mid-point (mi-lieu) between drying out and drowning, as optimal for its survival. For some species, this optimum can be recognised along a slope, in which high is dry and low is wet. But, per species this tolerance can be studied for any environmental variable (e.g. the presence of chalk, phosphorus or nitrogen). It would thus make sense to take variation itself as an environmental variable for humans.

Quality is scale sensitive
The relationship with boundaries of acceptability on both sides (as depicted in *Fig. 6*) may exist at any level of scale, although in a different form at each level. For example, if you approach a building, you first may see the whole separated into some larger parts, as components of a composition, at the scale of the building as a whole. As you approach the building at a smaller distance, one part will cover the scope of your vision. Your eyes may search for a smaller second composition within that part, with smaller components (possibly known from other buildings), in order to make sense of what you are seeing.

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[a] Birkhoff(1933) *Aesthetic measure* (Cambridge, Mass.) Harvard University Press
[b] Bense(1954) *Aesthetica* (Stuttgart) Deutsche Verlags-Anstalt

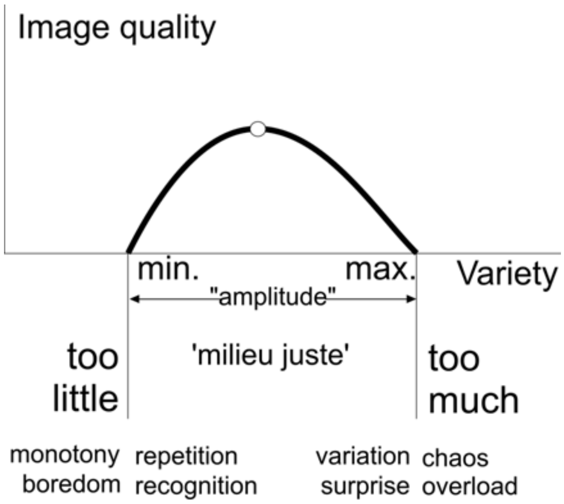

Fig. 6 Visual quality related to diversity

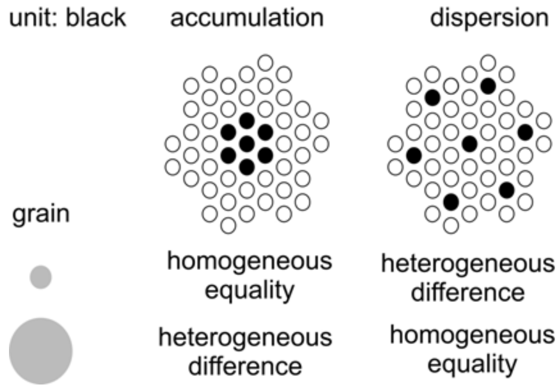

Fig. 7 Scale-paradox

Finally you may approach the entrance, with its even smaller components and details in the composition of the entrance, probably recognising elementary building materials. This crucial relationship between diversity and scale, as determined by the resolution of our senses had not yet been noticed by Birkhoff and Bense. At one level of scale, you observe differences, while you may recognise equalities at another level (scale-paradox, see *Fig. 7*). A scale difference of factor 3 transforms the observation into its opposite. If at different levels of scale a, b and c the variety (ranging from equality E into differnce D) may differ as $E_aD_bE_c$ or $D_aE_bD_c$. You may name these alternatives 'variety accords'.[a] The appreciation of diversity (see *Fig. 6*) at different levels of scale (see *Fig. 7*) may explain why disciplines may have opposite opinions about quality. Architects and urbanists may refer to different levels of scale. The innocent observer, however, will experience a pleasant alternation of surprise and recognition approaching a spatial object. Successive smaller compositions may offer arousal through surprising stimuli and rest through the lack of stimuli passing recognisable patterns.

Functional quality ⇓ limited morphological diversity

The balance of *Fig. 6* may apply to the visual quality of Vitruvian 'grace' as related to the diversity of form. We must then ask, however, whether it also counts for utilities other than 'grace'. For example, a flat ground in the open air offers no other functions than for reclining, sitting, standing and walking. A slope already offers the opportunity to sit and rest with some more comfort, to climb and to descend, or to have a narrower or wider view. A wall provides shade, an enclosure safety and a house with rooms affords a multitude of possible functions. They represent an increasing morphological diversity as a condition for an increasing number of uses and choices (functional diversity). Potential function may thus be related to diversity. Any function requires at least one difference. In the example, it is the simple difference between ground and air. This is the lower limit of diversity. Is there an upper limit as well? In other words, is there a value of diversity at which a function starts to fail? Answering this question requires a closer look at 'structure', which lies between form and function; it is often invisible, but it apparently conditions the functions other than 'grace' more directly than form does.

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[a] Ravesloot;Apon;Boelman(2005) *Aesthetics in urban design seen from the perspective of sustainability* (CostC12EU) TaylorFrancis, this article describes an application of variety accords in:
Jong; Ravesloot(1995) *Beeldkwaliteitsplan Stadsdeel 'De Baarsjes' Amsterdam*. (Zoetermeer) assignment Stadsdeel De Baarsjes Amsterdam to MESO

Function ⇓ structure
The relation between function and structure depends on scale. At a certain level of scale, a structure may have an external function. This function has no meaning, however, without a concept of an even larger external structure in which it functions through connections and separations at *that* level. For example, if you ask somebody, “What is your function?” then (s)he may answer, “Director”. To know what the function actually is, you must ask further, “Director of what?”. It makes a difference whether the answer is “a one person household” or “a company”. ‘Function’ thus supposes a larger structure of which it is a part. Within this larger structure, a function may have connections and separations in different directions. At the beginning of this paragraph, however, we stated that, at a certain level of scale, a structure may have an *external* function. The resulting *internal* structure is something other than the larger *external* structure. It refers to a smaller level of scale. Any element of that smaller structure may again have a specific ‘function’ within that structure and this ‘function’ is definitely something other than the function of the smaller structure in a larger whole. Structure and function are thus scale-sensitive, as I previously concluded for visual functions. They have no proper meaning without reference to a level of scale.

Structural quality ⇓ at least some morphological diversity
This still does not answer the question of whether any function other than ‘grace’ may have an upper limit in the diversity of its morphological appearance. It does, however, allow us to shift into the question of whether any invisible *‘structure’* has a relationship to morphological diversity, and whether this relationship has lower and upper limits. For example, in building mechanics *size* counts. If you make a beam too thin according to what it has to bear, the structure will fail. On the other hand, it will also fail if you make it too thick in relation to its span as a consequence of its own weight. In larger constructions (e.g. bridges) you can take away the parts that do not contribute to the function of spanning. This saves own weight and it results in a kind of parabolic form well-known from many bridges. It divides the functions of its elements into connecting (stress-taking) and separating (pressure-resisting) components. It visualises the structure that is already present, but hidden within the beam. Incidentally, in the stripped definition of form (pure dispersion in space), this form may be invisibly present, hidden within a beam. Form can thus also be independent of human vision or touch and, consequently, from meaning. It may be invisible, but it can be visualised in a drawing. Anyhow, you can conclude that structure supposes some morphological diversity.

Structure ⇓ form
At this point, I leave aside the question of whether this is the case in other fields (e.g. the physics of temperature transition in a window) or at other levels of scale (e.g. the structure of a landscape or its infrastructure of connections and separations). One example is sufficient to prove the *possibility* of a relationship between morphological diversity and structure. The possibility of *not* having such a relationship, however, requires at least one example as well. I have not yet to find one. If someone claims to have in mind a structure a structure without a form, you could ask this person to explain that structure. (S)he would then take a pencil and a piece of paper and draw objects connected to each other in various ways by lines. You could then ask “Are you not drawing a form now?”. The answer would likely be “Yes, but the points and lines could be changed in size, and that would change the form. Regardless of its form, the structure remains the same”. This would be precisely what you wanted to hear, as you could now finish the discussion by saying “That is even worse for your argument, because it covers an entire *set* of forms!”. It merely proves that the same structure may have many forms. It does not matter which form, but it must have a form in order to be operational. It supposes form. Structure ⇓ form. Any time you want to express or explain it you must give it one of these forms. Incidentally, explain (i.e. ex-plain) something is litterally to distribute it in a plain. Even if we imagine an abstract structure of separations and connections, this structure supposes the directions of these separations and connections, as well as some distribution in space. Even if it is topological, it supposes form.

Structural quality ⇓ an upper limit of morphological diversity
By concluding that there is a conditional relationship between form and structure, the question of whether any higher degree of morphological diversity has *limits* for the proper operation of a structure remains to be answered. The lower limit is clear: you need at least two different objects separated in space or time in order to connect them. However, suppose that there are x different objects that can be connected or separated in x^x ways. If you choose one way to connect them, there would still be numerous possible patterns for the same structure. This kind of morphological diversity thus does not influence the structure unless you take the total length of the required connections into account. This may influence its operation. If you increase the *number* of different objects x, however, the number of differences would increase as well, and even more with x^x, which would increase another kind of morphological diversity. If all objects need some kind of connection within the structure, then a structure will be more diverse according to the increased morphological diversity. This implies a relationship between morphological diversity and structural diversity as we have already established. This still does not answer the question of whether there is an upper limit. A limit appears as soon as the connections and separations themselves need space. For example, if all dwellings in a neighbourhood should be connected to the public infrastructure, you cannot add dwellings by building them on the surface of the road. If space is limited (as it is in any spatial design), there will inevitably be a point at which the increasing number of objects cannot be connected or even separated. This point should be the morphological upper limit for the proper operation of the structure for which we were searching.

Independent structural diversity
This inference shows something else as well. Until now, we have limited our discussion to the influence of *morphological* diversity and diversification. The chapter titles in this study, however, also mention *structural* and *functional* diversification. Do these diversifications then have their own kind of diversity that is not covered by the underlying morphological diversity? For example, the structure of roads is largely characterized by a hierarchy. On average, every third residential street may be a neighbourhood road. Every third neighbourhood road may be a district road and so on, with urban, regional, national and continental highways. Moreover, there are networks for drinking water, sewage, data transmission and other matters. It is not difficult to understand what is meant by structural diversification or to understand that such diversification is likely to be limited given that any structure requires space. *Functional* diversification beyond its morphological grounds is more complicated, however, as it allows creative humans to enter the scene.

Independent functional diversity
Without a doubt, a wide diversity of functions remains possible, even independent of the underlying morphological diversity. The same room can accommodate many functions. Nevertheless, is there some upper and lower limit to its multi-functionality? For example, consider different types of pocketknives. An increasing number of functions (e.g. screwdrivers, awls, bottle-openers, corkscrews and even tongs) can be added to the original knife. At a certain point, however, the knife can become difficult to handle. Comprises in construction reduce the quality of the knife, the functions hamper each other and the knife no longer fits in your pocket. If you were to have only the blade, however, you would not be able to handle it either, and it would destroy your pocket without an additional function of coverage. Function may thus also have limits of multi-functionality – limits of a potential diversity of use. Too many or too few potential functions combined do disturb an effective use. In such cases, there may be an upper and lower limit of multi-functionality. This is not the place to elaborate the further complications of functional diversity and diversification. Its meaning in science and humanities is addressed in the next section and in Chapter 6. At this point, I present several preliminary conclusions about the intended relevance of this study for spatial design and technology.

Relevance for design and technology

Functional diversity has lower and upper limits. Potential functions must remain operational during their use and until a subsequent performance. They need a stabilising structure, without which they cannot be relied upon when making plans and focusing activities. This does not necessarily negate the importance of temporary opportunities. Such opportunities are a source of innovation. Nevertheless, there should be a balance between that which changes and that which remains the same within your environment. There should be a stabilising structure upon which you can rely, but it should leave possibilities for change, unexpected opportunities, affordances that may surprise and challenge. This is structural differentiation, which has its own upper and lower limits of economical technology. But, what if nobody is *aware* of these affordances? What if nobody is attracted by them? Morphological diversity on its own is a primary condition for distinctive awareness. A certain amount of repetition, however, is a secondary condition. Repetition enables recognition. Somewhere between recognition and surprise, the affect of attraction (i.e. 'grace') may appear. The diversity of form also has lower and upper limits. In addition to spatial repetition, this discussion concerns repetition in time (i.e. a presence in memory). This study attempts to extend the available means of designing to achieve appropriate morphological, structural and functional diversity at different levels of scale and their development (diversification).

1.3 Empirical science and the humanities

Limitation shows the master
Empirical researchers from specialised sciences and the humanities usually do not appreciate this kind of all-embracing reasoning about design or discussion of in terms of possibilities. They will say to you, ‘Limitation shows the master! What is the problem you want to solve, your aim, your hypothesis, your theory? What are then the research questions to be answered, how are you going to answer them, what is your method? What are your starting points, your references, your variables. What is your data set, how do you collect the data, how reliable are they? How are you going to report the results?’ I will try to answer some of these common questions in Chapter 2, because they make a study accessible for critique, and this is a crucial scientific criterion, even in the perspective of possibility.

Completeness of view
Yet another scientific criterion, however, has nearly been forgotten in contemporary science and the humanities since Descartes. It is contradictory with the limitations referenced above. This criterion concerns the requirement of completeness. The supposition that a synthesis of specialisations will ultimately cover possible realities does not hold. Although it may be an unattainable ideal, an architect neglecting the front-door or the kitchen of a house – thus ‘showing the master’ by limitation – will not easily get new assignments. You cannot suppose the rest to be the same (‘ceteris paribus’), as the context always differs in spatial design. In environmental design, you are not faced with a single, well-defined problem, but with a field of connected problems. There is no single aim, but a field of aims represented by the many stakeholders and specialists involved. You cannot neglect any of them. Your hypothesis is the design itself, and this is precisely what requires the major effort.

Possibility search has other limitations than research
The limitations through which designers show their mastery may differ from those faced by researchers. First, designers work within a highly specified limitation of scale, even if the design has yet to be made. The largest and smallest relevant measure of the intended object limits the study substantially in space and time. Second, the variables to be taken into account are limited by their relevance according to that scale. The rest is context, which is not limited by scale, but by the administrative, cultural, economic, technical, ecological and spatial effects that must be taken into account, whether intended or not. This context may produce a verbally limited program of requirements, but that is not the whole story. The location limits the design project in its form, structure, function and political intention, including the limited possibility of changing them. Other important limitations in design include the experience, the portfolio, the repertoire and the references of the designer. These aspects are more important for determining whether the person fits the assignment than are the limitations faced by researchers. The scientific relevance of this study may thus lie in the fact that these limitations, and the variables involved, receive more attention in science and the humanities. If this is the case, I must explain their meaning in more detail and discuss how empirical research could help to gain a better grasp on them.

Probability ⇓ possibility
The requirement of completeness comes into conflict with the practical requirement of limitation if that limitation forces us to neglect relevant contextual factors. In empirical research, contextual factors are often neglected due to a lack of data. They are replaced by a ceteris paribus assumption (‘all other things being equal’). In a spatial design, however, the context is never the same. Moreover, if the design has yet to be made, this ever-changing context is the only thing there is. The object itself does not yet exist. To an empirical researcher, this is bizarre. How can you study something that does not exist? For a designer starting a job, there is only an administrative, a managerial, a cultural, an economic, a technical, an ecological and a spatial context. Although the context may provide a program of requirements, it is based largely on earlier empirical *ceteris paribus* results from other

contexts. Furthermore, it can still be changed by sketching other possibilities that take advantage of unique local characteristics. Designers thus complain about the generalising character of empirical research and its lack of context-sensitivity: 'That may be true on the average, but not in the specific context of this project!'

The integration of specialisations by design

Any design project of appreciable size involves many stakeholders and specialists from the administrative, managerial, cultural, economic, technical, ecological and spatial contexts. A designer is asked to capture all of their claims and programmes in a single spatial concept. This concept is a hypothesis, which is subjected to preliminary testing by the accidentally composed team of specialists representing the contextual sectors mentioned above. They may have conflicting overlaps and unavoidable gaps. Even the elaboration of the concept into a more detailed design is still a hypothesis. Its hypothetical quality cannot be definitively falsified until it has been realised. Instead of facing a single problem to be expressed in a simple problem statement, therefore, a designer faces a *field* of problems to be balanced and 'solved' in the concept. This field is difficult to express in a one-dimensional verbal or mathematical language. Expressed in this way, these problems seem vague and full of loose ends. You may immediately recognise them in a drawing, however, where every direction tells a different – and sometimes opposite – story. This type of expression is another language, and it is not very convincing in science and the humanities. It is not a language of true and false. It is a language of possible and impossible. It explores the possibilities of matter in multi-dimensional space. It is a weaving of loose threads often spun by earlier scientific efforts. It often loosens the thread of these stories outside the actual weaving, as there are so many threads to be woven. Although it may be incoherent within the line of a scientific inference, it finds its coherence in the other directions provided by space.

Gaps and overlaps in the weaving of specialisations

Science and the humanities have been subdivided into an ever-increasing number of specialisations. The tacitly shared supposition is that they once will ultimately fit together to cover the whole of that which can be known. Any specialisation with its own peer-reviewed journal hesitates to enter the territory of colleagues from other specialisations. Their territories overlap nevertheless, and they leave gaps. The overlaps are hidden by the jargon that makes a specialisation inaccessible to other specialists, as well as to the innocent people who must pay for their efforts. The same things seem different only because they are named differently. A lack of overview prevents the gaps from being fully recognised. Who has had an overview since the *uomo universale* of the Renaissance? The more you think you know, the more gaps you discover.

Introducing other variables

Given the points discussed above, what could this primarily design-related study contribute to science and the humanities? First, it may draw attention to some still 'vague' variables that have thus far not been recognised as accessible to science and the humanities (see Chapter 3). It attempts to make them more explicit in relation to scale. Variables are one-dimensional by nature. They belong to the linear language of science, spinning an unbroken line of thought, ceteris paribus avoiding the side-roads. This weft misses the cross-roads of a warp as they are inevitable in designs represented in drawings. The missing threads of 'vague' variables may fill gaps in the weaving. They may bridge gaps that designers are accustomed to filling with drawings and vague verbal justifications. However, designers do not primarily think in variables. They think in discrete values and in legend units dispersed in their drawings, which acquire local connections and synergy. However, there may be unused values in the range of values composing a variable. This could enrich the legend of the drawing through the inclusion of intermediate or external values. The interpolation and extrapolation of empirical values may thus open unexpected possibilities for design. Raising awareness with regard to this possibility may pose a scientific challenge. On the other hand, there may be loose values applied in design that cannot be captured within the logical sequence of a variable. How should we cope with them in a scientific manner? This question is inherent in the broader question of how to cope with diversity at all. Science searches for generalisations, equalities and equations that are valid in different contexts. Design searches for differences that may be overlooked or that may become possible. How should we cope with *possible* diversity? This question continues to bother me. I do not pretend to answer it in this study. It could even be that the inconceivable diversity of nature and of the possibilities for design will ultimately remain inaccessible to science.

Elusive form

The dispersion of values in a drawing (as expressed in the legend), seldom obeys the sequence of these values as they would be ordered in a theoretical variable. They largely appear as loose values scattered in space. Their harmonious or contrasting relation to adjacent elements is full of effects that are difficult to describe. The scientific or mathematical description of possible dispersions has been attempted in geography[a] and ecology,[b] but it it has yet to be resolved sufficiently. There is the problem of form and shape, which is often neglected in scientific approaches. For example, the essential form of a piston fitting into a cylinder has not yet been represented in the thermodynamic formulas that describe the processes that take place within a steam engine or a petrol engine. The Wankel engine could not be derived from thermodynamics. It could only be described after its invention. The combinatoric explosion of possibilities for distributing different materials in space remains a challenge for scientific description. This is painfully obvious in the comparison and analysis of designs. The solution certainly requires the articulation of scale. This may be one important suggestion of this study. It is only the very beginning, however, of a scientific approach to morphological differentiation.

Scale and resolution

Even a weaving will reveal gaps if you look at it closely. If the gaps of a gridiron are small enough to walk upon, however, should this matter for design? Any object of design has a cross-section with its largest measure. The scale of this object may be expressed most simply by the radius R of the smallest circle or globe circumscribing the object (its 'frame'). Less recognised, however, is the smallest measure taken into account by a designer. An architect need not take every molecule of the object into consideration. There is also a lower limit. For building design, this limit is the building material (e.g. a brick or a beam). Its scale may be expressed most simply by the radius r of the largest circle or globe it can contain ('grain'). Smaller gaps of knowledge need not be filled in order to make a proper design at the level of a building. The 'resolution' of the design is thus determined by r/R. Resolutions of 1/10, 1/100 or 1/1000 refer to a rough sketch, a proper drawing or a blue print showing all details, respectively. They are the spatial limitations of design thinking. There are similar limitations in time.

Opposite conclusions possible at a subsequent level of scale

The limitations in scope and resolution that are described above are common to all reasoning. Even scientific disciplines may have resolutions that are determined by the outer and inner limits of their scope. For example, it may be possible to sort the various ecological approaches (e.g. landscape ecology, systems ecology, syn-ecology, aut-ecology or chaos ecology) according to their scale of interest and resolution.[c] What may be true at one level of scale may be false at another level (scale paradox, see *Fig. 7*). For example, if a small town of R=1km grows to R=3km, it may acquire a new city centre serving the surrounding districts R=3km. The shops of the district centres R=1km may decline in competition with the main centre, but the smaller R=300m neighbourhood shops will receive new opportunities. The

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[a] Haggett (1977) *Locational analysis in human geography* (London) Arnold

[b] Pianka (1994) *Evolutionary ecology* (New York) Harper Collins College Publisher

c Jong(2007) *Urban ecology, scale and structure* **IN** Jong, T.M.d.; Dekker, J.N.M.; Posthoorn, R. *Landscape ecology in the Dutch context: nature, town and infrastructure* (Zeist) KNNV-uitgeverij p380 *http://team.bk.tudelft.nl/Publications/2006/Landschapsecologie/Onderdelen2/Urban%20ecolog1.doc* scale paradox thus offers an explanation for the opposing recommendations of the different approaches, as frequently encountered in design-related problems. Accurate consideration of the level of scale may transform such scientific conflicts into complementary insights. Each level of scale thus gains its own disciplines. You should not ask a specialist in scale R=1km to provide advice regarding an object of scale R=10km. Scale articulation rationally limits the kind of categories and variables you must take into account. For design-related questions, this limitation of research variables is preferable to an implicit and arbitrary ceteris paribus supposition.

Structures breaking usual relations

The subsequent study of *relations* between variables is a common scientific practice. The values of different variables may influence each other. If these values are expressed in the form of legend units in a drawing, however, these probable connections can be broken by separating structures. For example, if the level of the sea becomes higher than the land, flood is probable. If we build a dike, however, it would be possible to avoid such flood. Conversely, if we have shops at some distance from a residential area, we can build a road or organise public transport to connect them. A structure of separations and connections thus increases the possibilities for use and allows choices that would not be probable without these design interventions. Connections and separations usually receive their own legend units in the drawing in the form of *lines*. They obey laws that are different from those of categorised *surfaces* with their probable mutual effects.

Opposite conclusions possible in different directions

One of these conjectures, published by the ecologist Van Leeuwen,[a] refers to the phenomenon that a separation appears perpendicular to a connection (direction paradox). A road causes a barrier perpendicular to the direction primarily intended to connect. These ‘side effects’ are often neglected in the straightforward causal reasoning of empirical specialists (e.g. traffic specialists calculating the expected traffic load). The development of increasingly complex systems of connections and separations may be called structural diversification. Connections and separations select contents, stabilise patterns and regulate processes maintaining less probable local states of low entropy. Structural diversification is the spatial counterpart of cybernetics and very recognisable in living systems. Your skin breathes, selecting what comes in and goes out, as do all other cells in your body. The content inside the cell is structured by numerous membranes that select the contents, stabilise the composition and regulate the processes on both sides. If these membranes are broken by chemical substances or a bullet, you will die.

Selectors and regulators

Structure is thus simply the set of separations and connections. It comprises construction, infrastructure and any other elementary combination of separations and connections in different directions. Van Leeuwen called them ‘selectors’. *Fig. 8*, shows them separating in 1, 2, 3, 4 and 5 directions while simultaneously connecting in 5, 4, 3, 2 and 1 directions. In *Fig. 9*, these directions and types of selectors are depicted with time as a dimension (regulators). Separation and connection have some relation to difference and equality respectively. To the best of my knowledge, however, no existing scientific instrumentarium is sufficient to cope with this area of study, which is so familiar to designers. However, designers still do not call it structure. This impedes communication. Designers use the term ‘structure’ to mean ‘pattern’, which is a recognisable regularity in a form. It is the only discipline to use ‘structure’ in this exclusively morphological sense.

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[a] Leeuwen(1973) *Ekologie* (Delft) TH-Delft, Afd. Bouwkunde 3412b, Vakgroep Landschapskunde en Ekologie Hb 20 A http://team.bk.tudelft.nl/Publications/2005/Leeuwen/Leeuwen(1973)Ekologie(Delft)THD%203412b.pdf

Fig. 8 Elementary selectors in space

Fig. 9 Conditional selectors

Diversification beyond variables

In the beginning, you may have thought that environmental diversification could be fully covered by naming the relevant variables, distinguishing their values and searching for relations between them. This process, however, serves only to differentiate the content and some probable relations of an environment. The content is a reduced set of implicit or explicit legend units that you may use in a design, often breaking the usual relations. The content still does not cover the diversity that can be created by design. It neglects the diversity of possible distributions of the legend units in the drawing, their concentration or sprawl, or their form. Even if you had thought that environmental diversification was fully covered by including such morphological diversification, I may have disappointed you by introducing another kind of diversification – a 'structural' one, to stabilise, select, regulate and condition the content and its pattern. Even this is not the end of the story. Suppose that there are two environments with exactly the same content, the same distribution of elements in space (form) and the same structure separating and connecting them. Even if all of these aspects are the same, people can *use* them in different ways.
Differences in use thus cause a *functional* difference between the two environments.

Internal and outward function

I must discuss the term 'function' at some length, as it has many and crucial meanings in various disciplines of science, the humanities, design and technology. One excellent translation of 'function' is 'working'. This translation immediately indicates two meanings: the way in which it works (operation) and the type of work that it does (performance).[a] Operation is thus an internal working, and performance is an external working. Given that 'operation' can be described as a combination of selectively separating and connecting in different directions, it will suffice to interpret operation as the temporal counterpart (internal functioning) of structure. It is more difficult, however, to describe an external 'performance' in these terms. Performance refers to any possible use by humans. The performance part is gradually separated from the operation part in the following remarks on function.

Function and functioning

Both 'function' and 'working' exist as both nouns and verbs (or their conjugations). As a noun 'function' describes a partial working within an assumed larger structure. For example, organs have a function (*a* performance) within an organism. As a verb, 'to function' describes a part of the workings within an assumed procedure. For example, chemical conversions 'function' (perform) within a food chain. 'Function' thus possesses 'space-time duality'.

Structure and structuring

The verbal form of 'structure' (to structure, structuring) does not indicate its own action (to operate, operating), as is the case with 'functioning' (performing). Structuring indicates an external action through which structure is *given* to some object. For designers, however, this verb refers to assigning some order or regularity – a recognisable pattern – to a form. Designers do not refer to the process of assigning a structure to the form, as intended in 'the structure of a builing'. I am glad that there is a verb ('to structure') for stabilising an object at any level of scale by connecting and separating its parts. Could we not say 'ordering', and reserve 'structuring' to mean the process of assigning operational separations and

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[a] Tzonis(1992) *Huts Ships and Bottleracks Design by Analogy for Architects* IN: N. Cross, K. Dorst and N. Roozenburg *Research in design thinking* (Delft) Faculty of Industrial Design, Delft University of Technology the Netherlands, Proceedings of a workshop meeting

connections? In neither case, however, does ‘structuring’ have the same relation to ‘structure’ as ‘functioning’ has to ‘function’. ‘Functioning’ may be subdivided into the outward *performance* (by the function) and its inward counterpart, the *use* (by the user). Both are external to the function. This raises the question of whether a comparable verb exists for the external action of giving or *changing* a function. To ‘use’ a function is an external inward action, but it does not involve a fundamental change to the function, as do structuring or restructuring, which either *give* or *change* structure.

Changes of function

Changes in function often appear as a division or a combination of functions, thereby resulting in more mono-functional or multi-functional devices. The combination of functions may save space at the expense of the time required to use them, while the division of functions saves time at the expense of the space required to divide them. For example, dividing a road into lanes for public transport, private cars, cyclists and pedestrians saves time or even lives (and consequently lifetime), but it requires more space. I am not aware of a verb that covers both as the result of an external inward action. Their distinction is important, however, if you wish to understand functional diversification as intended in Chapter 6. Designers often combine or separate functions in an unconventional manner. Nonetheless, functional diversification does not necessarily suppose any external action (e.g. by a designer). It may be an autonomous, ‘emerging’ process (e.g. as known from embryology).

A function may have many sources and destinations

Aside from its possible change or its meaning as a noun or a verb, ‘function’ supposes a destination for the working of the function: a structure or a procedure in which the function takes place. In many cases, the verb tacitly supposes this structure, indicating only one of its elements as the destination. This destination is the object y, which is affected by one ore more subjects x. In most cases, x is interpreted as the *cause* of the effects on y. Even apart from y, however, the subject may have side effects on other objects in the environment. The environment must therefore be made explicit as a structure, with many connections and separations. This is even more urgent if the function of x is not only causal, but also conditional.

A function is context-sensitive

Side effects are often overlooked, and they can be different in different contexts. If this is the case, they will fade when the average effect is very convincing. The sum of the side effects of the same function in different contexts, however, may be more serious than its main favourable effect. For example, if a medicine has different side effects for different people, some of them may be so rare that they cannot be proven by statistical means. On the other hand, that ‘some’ may be many. Nobody knows, as these effects cannot be proven if each time a specific effect occurs for one very specific person within a very specific context. Function is thus a context-sensitive concept.

A function is direction-sensitive

Moreover, spatial subjects have different effects in different directions. A road connects in one direction, but it also separates perpendicular to that direction. A cause may have different effects in different directions. This demonstrates the limitation of verbal expressions. An inference or verbal expression has only one direction, whereas a drawing has many. ‘Function’ is thus also ‘direction-sensitive’.

‘Function’ has a part-whole duality

One special case of direction-sensitivity is the ‘part-whole duality’ of any function. The function of some subject s for its context c=f(s) is something different from the function of a context c for that subject s=f(c). The subject has become the object. The director ‘of’ a company is a function ‘of’ somebody ‘for’ that company. From the company’s perspective, however, the company has a function ‘for’ somebody. ‘Function’ may therefore indicate a relation of the parts to the whole or the other way around. A function is one-sided, as it is very explicit in mathematical expressions. The formula y=f(x) refers to the function of x *on* y. Function therefore has a dual meaning:

- as whole=f(part), the working of an active partial subject (source) in the whole of a larger structure (destination)
- or the reverse part=f(whole), the working of an active whole of a larger structure (source) on a partial object (destination).

'Function' thus also has a 'part-whole duality'. The distinction between source x and destination y then should be clear. Where a destination y exists, there should also be a source x, even if the source is not determined or even nameable. This is the case when you search for the source (cause or condition) x of an observed effect y, or when you design an effective artefact x for a function y. Even if the function y is known, the artefact x may not yet exist, if it has yet to be designed.

Top-down conclusions may be opposite to bottom-up conclusions

A subject can thus have a function for a larger environment (e.g. anatomy) or, more specifically, an object within that environment (in which case you must neglect the side effects on other objects). In contrast, an environment can also have a 'function' for its smaller elements (e.g. ecology). In sociology, this inward approach was accepted as 'structural functionalism' in the 1960s.[a] The behaviour of individuals should be understood in terms of the requirements of society. Structural functionalism evoked a reaction from the 'symbolic interactionists',[b] who sought to clarify society from the perspective of individual needs, which produce an urge to exchange and cooperate. In sociology, the approach from smaller parts into a larger whole acquired the name 'anascopic' (outward). The approach from large into small acquired the name 'katascopic' (inward).[c] The application of this forgotten distinction extends beyond sociology. Failure to distinguish between the outward and the inward approach can generate confusion. The conclusions of the two may appear to contradict each other. For example, a ball can be described outward as concave and inward as convex. A chairman searching for a compromise between convinced anascopists and katascopists could propose that the ball has an undulating form. Many compromises in science and the humanities show this kind of bias. The function of a tool for its user is largely outward, while the function of a house for its inhabitants is inward. A house is thus not a tool, as some may claim. Architecture is something other than industrial design.

The double-edged function of a boundary

Yet another duality exists as well: the problem of a boundary as an acting subject. What is the function of a boundary? The lines drawn by a designer consist largely of boundaries. If the functioning subject is a closed boundary, this double-edged separation influences at least two different objects: the interior *and* the exterior. In this case, 'function' may refer to both inward and outward influence. For example, the walls of a house may keep the inhabitants warm and safe inside, while having an impact on the flow of the wind and the visibility of the landscape on the outside. The function of the wall has no unequivocal source or destination; it influences other functions – each with its own source and destination – in different ways. It obstructs external functions (wind, accessibility) and it makes different internal functions possible. The boundary is not 'active' in and of itself; it *prevents* and *allows* actions. It *conditions* other functions (as always happens in spatial design). The 'function' of separations and connections may thus also have a 'boundary duality', which blurs the clear distinction of source and destination.

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[a] Parsons (1966) *Societies: Evolutionary and comparative perspectives* (Englewood Cliffs, N.J.) Prentice-Hall
[b] Zijderveld (1973) *De theorie van het symbolisch interactionisme* (Meppel) Boom
[c] Berting (1976) *Ruiltheorie* (Intermediair)0528

A function is scale-sensitive

The meanings of 'function' differ substantially at different levels of scale and time spans. For example, CO_2 has a different function for a plant in its lifetime than it does for the Earth during its existence. Given the many tacitly assumed levels of scale in science and humanities, scale confusion leads to language confusion. It is therefore unacceptable to speak about a function without mentioning the assumed spatial or temporal level of scale of its intended working. This level of scale determines the variables that must be taken into account. Although this form of scale sensitivity may seem similar to the parts-whole duality, it is something else. As stated before, the part-whole duality can play a role at any scale.
Limits of unidirectional language
'Function' is used in many contexts, thereby acquiring a variety of context-sensitive meanings, each of wich assumes a different source and destination. Empirical research primarily distinguishes and names a single destination as the effect y. The observed effect is a crucial part of any problem statement: 'Why y? How y? What causes y?' The effect should thus be clearly bounded. From this perspective, you can efficiently search in different directions for a cause, the unknown or suspected 'x' and its working on y. In some cases (e.g. exploratory research), x may be unknown, while in others, it is made explicit in a hypothesis to be verified of falsified. In some situations, a combination of different causes x may be accepted if no other option available. A combination of effects y is more difficult to accept, as it blurs the problem statement.
That limitation of y and x may also be forced by the verbal language required to express and report the results. In linguistics and logic, a 'complete sentence' indicates the intermediate position of a verb (an operation or a performance) between a subject and its object. In a complete sentence formula y(x) – to be read as 'y as a working of x' – the verb is expressed indeterminately by the brackets ( ), thus enclosing 'x' as an active subject. A mathematical function f(x) may quantify the working between 'variables', usually distinguished as a single dependent variable y=f(x) and one or more independent variables x. In physics, 'function' relates cause x and effect y (or its probabilistic equivalents). In biology, it relates organ and organism, while in sociology, it relates individual and group. In design and technology, function relates artefact and environment (including the user).

Chicken-and-egg duality

The field of biology, however, has struggled with a chicken-and-egg problem between cause and effect. The effect can become a cause in a repeating sequence, thus blurring the usual cause-effect (c-e) sequence. The problem emerges in the many feedback systems observed in biology or technology. The imagined effect subsequently influences the cause through feedback. Whenever humans are involved, a given situation can even raise a plan of successive actions (procedure), in which the imagined result *precedes* the realised actions as a 'goal'. The imagined 'goal' (an intended result of action) subsequently becomes the *cause* of the actual action. This raises the question of what is the cause and what is the effect: y(x) or x(y)? To avoid confusion, the process c-ec-e must be subdivided into proper c-e cause-effect components in order to avoid an e-c sequence. In this process, 'function' may acquire a 'chicken-and-egg duality'.

Eufunctions and dysfunctions

Finally, a normative distinction exists between eufunction and dysfunction. This distinction is also rooted in sociology. From the perspective of the survival of a society, a criminal is usually assumed dysfunctional, while a citizen practising the society's values is assumed eufunctional. In biology, eating is eufunctional, while being eaten is dysfuctional. Even 'using' implies withdrawing means from other potential uses at the same time. For example, to provide families with safe, warm housing may have undesirable effects at a larger scale, due to the exhaustion of energy resources. At a smaller scale, such provision could make the inhabitants more vulnerable by allowing them to become accustomed to a safe and warm environment, thus catching a cold as soon as they open a window or leave their homes. In many cases, the word ‘function’ is implicitly used as ‘eufunction’. We sometimes use the phrase ‘not functional’ when we mean ‘not eufunctional’. The word ‘malfunction’ supposes a disappointing eufunction (the ‘proper’ function), but not yet a ‘dysfunction’. In this way, many (if not all) eufunctions may have dysfunctional side effects or costs. ‘Functional’ has two normative faces that must be balanced as a value for survival by decision-making. In its foundation, ‘normative’ refers to any assumption about the impact of human action on the life expectancy of living sets. ‘Life expectancy’ assumes a time left to live, along with its ‘value’. The ‘living set’ may consist of individuals (liberal values), families (confessional values), communities (social values) or even include other life forms. This is the subject of the following paragraph.

Different evaluations of function

The distinction between eufunction and dysfunction bears all of the ambiguities associated with the term ‘function’, as mentioned above. Any evaluative assessment demands explicit mention of these ambiguities. You can assess the function as an object expressed in the form of a noun (do we need it?) or in the form of a process (does it work?). You can assess how it works (operation) and what it does (performance). You can criticise the side effects, thus stressing its context sensitivity. You can compare the impact of the function in different directions, and you can balance its profits and losses in all of these directions or in only two, in order to assess the function of a boundary. You can consider the profits for the whole or for the sum of its parts. You can repeat all of these assessments at any level of scale. Finally, you can assess the profit for a chicken or for an egg.

The relevance for science and the humanities

The second ambition of this study is to be understandable, relevant and useful for science and the humanities. This ambition must apparently remain under the shadow of the relevance of science and the humanities for design and technology, and it therefore has a strong chicken-and-egg character. Many design questions involving function, structure, form and content remain inaccessible to science and the humanities. Questions about functions seem to be most accessible. They are answered by programming and evaluating research. There is nevertheless considerable language confusion regarding the many meanings of ‘function’. Designers assume many functions in their designs that do not perform as expected after realisation. Other functions or ‘effects’ still cannot be expressed in researchable terms. At the level of a building (construction), ‘structure’ is scientifically well developed as chemistry, mechanics and building physics. At larger levels of scale, however, much work remains. ‘Form’ is underdeveloped. ‘Content’ continues to lack many scientifically explicit variables that are relevant in designs, and which are only partially explicit in their legends. The primary difficulty involves the expression of such open and ill-defined questions in a language that is accessible to empirical researchers. Conversely, researchers may become aware of the problems faced by designers in the process of making a drawing. In this regard, this study may help researchers to recognise some of the limitations to their own distinctions, language and methods. If they manage to extend these boundaries, a rewarding field remains to be explored.

1.4 Politics and decision-making

To cooperate or not to cooperate

At any level of scale, political and decision-making processes assess the desirability of functions; in some cases, they may change functions as well. Such assessments may be different in different spatial, ecological, technical, economic, cultural and managerial contexts. They are context sensitive and thus difficult to generalise. All political processes must nevertheless answer the same question: ‘What should we do together, and what is your own responsibility?’

In a democracy, the left wing of a political forum emphasises the left part of that question, while the right wing focuses on the right part. War, floods or starvation can force cooperation. Disasters increase the urge to do things together. Situations that you cannot handle on your own will shift your political inclination to the left. If disasters fail to occur, however, your prosperity and your own opportunities may increase. This makes you less dependent and less willing to pay taxes for public services you no longer need. Your political conviction will thus shift to the right.

Economical cooperation in public services

Even in the latter case, however, you must admit that some functions perform more economically at a scale greater than that of the individual household. You cannot always maintain your own army and police; you cannot build your own dikes around your house and grow your own crops at the same time. For this reason, you accept the necessity of dividing these tasks, selling your own specialisation while buying the others that you need. However, everybody’s business is nobody’s business. Who is going to build the roads that are needed in order to exchange goods and services? Who is going to build the dikes in order to avoid flood? Who is going to safeguard your property and rights? Who is going to provide the functions that are used by everybody when it is impossible to calculate your fee according to your share in and profit from common facilities? Moreover, if you do not agree with the owners of these facilities with regard to your fee, who is going to judge and punish? You decide to delegate this responsibility to a territorial public authority accepted by everybody. If this authority is not accepted by everybody, the threat of chaos and violence may drive you to accept a dictator who promises to restore law and order, or you may migrate to another country.

Technical breakthroughs change the context of politics

Although the situation described above may be a caricature of the political process, it does demonstrate the role of scale within the context of politics and decision-making. Given this role, it is reasonable to ask what each household should do on its own and what would offer the best economic benefits from sharing at the local, regional, national or even international level? The development of technology changed the economically optimal scale of many functions. The invention of printing (1439) decentralised knowledge and religious authority. The invention of the steam engine (1777) centralised the dispersed system of home production into industries concentrated in cities. The invention of the mobile petrol engine (1886) de-concentrated households into suburbs, while further concentrating specialised production. The invention of the transistor (1947) made computers and photovoltaic cells possible, thus re-arranging the optimal scale of many functions in both directions. Politics and decision-making must react to these technical (and thus economic, cultural and managerial) shifts of context. National competences must be transferred upwards to international governments or downwards to regional and local authorities. Although movements in both directions exist at any level of governance and decision-making, one ecological factor drives the necessary scale of many functions upwards. This factor is the growth of the human population.

Population increase raises new urgencies

The doubling of the global human population in the past forty years has decreased your space on Earth by half, from 10ha to 5ha. In one of his impressive letters to me, Evert Croonen wrote, 'You are not born to hear that you are redundant'. For millions of years, the Earth was inhabited by some three million people. With $100km^2$ for each inhabitant, they had ample to explore. They lived in small wandering communities of some 30 hunters and gatherers, exploiting an average of $10\ 000km^2$. They met each other every day from birth to death. Individuals were forced to adapt their behaviour and accept that of others, because without the others, the individual inhabitants would be lost. It is only very recently (10 000 years ago) that the world population started to increase, due to the neolithic invention of agriculture. This accounts for less than 1% of the period in which we learned to be human. It is not very likely that our genes have undergone substantial adaptation to the new context in such a short period of evolution.

Changing conditions for humans

In contemporary times, you no longer count on a small and stable community. Apart from your home and family, there is no stable context to reflect who you are. You are part of an anonymous multitude from which you are free to choose your own partners, although they belong to other networks. They can easily let you down, as there are many alternatives. You are an interchangeable alternative. You must compete with others in order to become a preferred partner. Within the context of this competition, you become inclined to identify other communities, nationalities or races as inferior. When you were five years old, you wanted to become famous; at 10, you wanted to become rich and at 15, you wanted to be attractive. Ultimately, you have always wanted to be someone else, in order to win the interest of others. You must offer something special that others cannot offer. It should not be too special, however, as otherwise you would not fit into the communities of the others you are trying to impress. This situation reflects a kind of tolerance similar to that depicted in *Fig. 6* and *Fig. 7*. On the other hand, you may belong to many communities, and you may thus have many identities to maintain. You have many specialisations that you can advance in order to make yourself interesting to others.[a] The often forgotten Dutch philosopher Carry van Bruggen eloquently clarified the crucial role of *distinction* in human life.[b] For many decades, this distinction was popular in Dutch political circuits..

Identity

In addition to economic questions, the contemporary political system must address an even more fundamental question: the pressing question of identity. Given its tertiary priority in this study and its economic interpretation, the political objective of this inquiry is elaborated briefly in one of the final sections (Chapter 6 on page 215, Chapter 7 on page 245). Public identity has currently been reduced to the information that a police officer might ask in order to determine your 'identity': 'name and address, please'. It is reduced to your origin in time (descent) and space (the place where you live). If descent has ceased to be important, the place where you live has become a crucial part of your identity. If it looks the same as those of everyone else, it fails to distinguish you from others. Within the context of this study, it should motivate territorially based political decision-makers to make living environments more diverse. It has to do with territory, the part of the Earth's surface that you defend as your unique property. Property has become more important since the neolithic revolution. It forced communities to remain close to their growing crops, due to threats posed by others. Human communities became sedentary. While the money-based economy and the industrial revolution made parts of your property mobile, they decreased the mobility of your dwelling place. Even if you move every seven years, you should have your own unique safe place, which is capable of protecting you and your other possessions until you return from any your travels.

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[a] Jensen; Wijnberg (2010) *Dus ik ben, een zoektocht naar identiteit* (Amsterdam) Bezige Bij. This booklet summarises the specializations through which you gain an identity: your thoughts (Descartes), your feelings, your work, your name, your community, your suffering, your past, your love, your acknowledgement, your consumption and your body.

[b] Bruggen(1919) *Prometheus* (Amsterdam 1986) Oorschot http://www.dbnl.org/tekst/brug004prom01_01/

The possibilities of diversity

Individual or environmental identity means *difference* from the rest and *continuity* in itself. If you are the same as everyone else, or if you change in such a way as to become unrecognised, it will be difficult to identify who you are. If your house is similar to those of many neighbours, or if your living environment changes dramatically, it will become difficult for you to recognise your place. In some disciplines, however, identity appears to indicate the opposite. For example, in mathematics, 'identity' is symbolised by the '=' sign. Identity thus appears to indicate an *equality*, even if the terms on both sides of the '=' sign *change*. It fails to address the question of why they are written down *differently* if they are equal. An equation has little use if the terms on both sides of the '=' sign are the same. If you look at the Latin background of the word 'identity', it appears to be a contraction of idem-tidem (*repeatedly* the same). It is sameness in time: continuity. For my purposes, this paradox is resolved in the regulation theory of Van Leeuwen.[a] This theory accepts that equality is a special *kind* of difference. Equality is thus a non-existent 'zero-point' of difference. In time, and continuity is a zero-point of change. Everything differs or changes more or less, even if it seems to be (or to remain) the same in many respects. This position seems to be at odds with sciences that attempt to *generalise*, and this touches upon the core of any inquiry into environmental *diversification*. Aside from this, Van Leeuwen made yet another discovery.

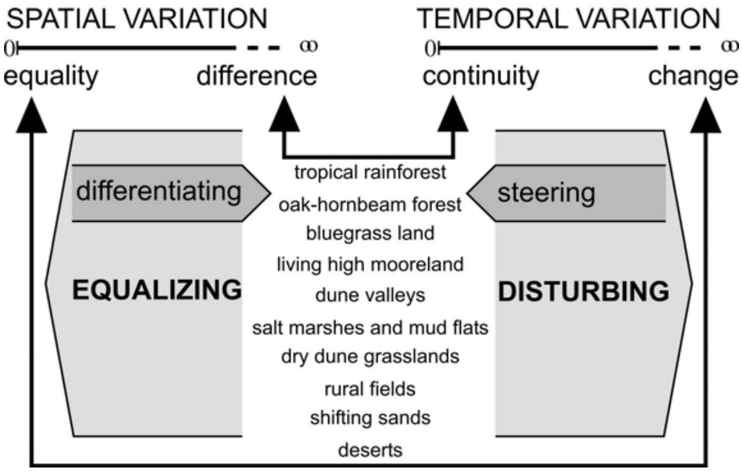

Fig. 10 Van Leeuwen's regulation theory

Within the field of ecology, diversity is often related to stability, near the zero-point of change. At some levels of scale, diversity and stability (tropical rainforest) appear to be related to equality and change (desert, see *Fig. 10*). Within this context, the mathematical '=' sign thus does not mean 'equals'; it means 'becomes' (:=). This reflects a change – a special kind of difference in time. This nonetheless fails to identify the cases in which you must still use the '=' sign. Even though the expressions on both sides may be different, they express different views of a reality that is assumed to be the same. It thus expresses different verbal representations of the same reality. Yet another difference remains: the frequently neglected difference between language and reality.

Arguments for diversity

Relevance for decision-making does not suppose to provide a proof of the *desirability* of environmental diversification. Although this thesis does not make this choice, it does support arguments for more solid and explicit motivation, based on the possibililties of diversification by design. The counterargument is obvious: 'Standardisation is efficient.' This, however, raises the question for whome it is efficient and at which level of scale in space and time. In the long term, Nature apparently chose for biodiversity at many levels of scale. After billions of years, this appears to have offered the best insurance for life against disasters and environmental change. Diversity is a prerequisite for the possibility of choice for future generations. These may be plausible arguments, but they do not yet represent a choice.

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[a] Leeuwen(1966) "A relation theoretical approach to pattern and process in vegetation" Wentia **15**: 25-46
Leeuwen(1973) *Ekologie* (Delft) TH-Delft, Afd. Bouwkunde 3412b, Vakgroep Landschapskunde en Ekologie Hb 20 A
http://team.bk.tudelft.nl/Publications/2005/Leeuwen/Leeuwen(1973)Ekologie(Delft)THD%203412b.pdf

Assumptions of identity

In addition to scientific arguments (e.g. sustainability, perception), philosophical and political arguments can plead for environmental diversification. An analysis of philosophical arguments leads to the concept of identity as difference from the rest and continuity in itself. Any political conviction is ultimately based on a portrayal of humankind, and any portrayal of humankind supposes a concept of human politics. Likewise, any political conviction implicitly supposes an answer to the question, 'Who am I and who are the others?' The answer to this question leads to the practical question mentioned previously: 'What should we do together, and what is your own responsibility?' However elusive the first question may seem, the possible answers to the second can be categorised systematically according to the level of scale. What should I do together with my neighbours or with the other inhabitants of this municipality, my country or my world? This question is relevant for policymaking in any political constellation. From these answers, the desirable kinds and quantities of environmental diversification can be derived. These answers even include environmental homogeneity as a special kind of diversification. The political objective and relevance of this study comprises such an analysis. It requires the creation of a terminology that enables a debate based on what is possible, rather than what we implicitly expect from other people.

'Diversity' is scale sensitive

In an attempt to develop a terminology that may be useful in design, science and policy, I set out to expose the typical ambiguities of diversity as a concept. In addition to being fatal when they emerge between science and technology, these ambiguities can enhance the appearance of consensus through the political manipulation of scale or other aspects (see *Fig. 7*). If an alderman promises only small dwellings to the inhabitants of an urban-renewal area, in an effort achieve a balanced size-diversification of houses, the residents could interpret this at the level of their neighbourhood. It is possible, however, that the alderman was referring to the scale of the town, thus realising larger dwellings elsewhere. Diversity is thus a scale-sensitive concept. At an urban scale, diversity may imply homogeneity at a neighbourhood level.

Relevance for politics and decision-making

Except for the political exploitation of ambiguities in order to camouflage conflicts, the existing terminology produces twisted reasonings if differences in the level of scale addressed in arguments and conclusions are not made explicit. If you claim that living, working, traffic and leisure hinder each other and should therefore be separated and concentrated in different parts of a town, the distance at which the nuisance actually has an effect may not be the same as the level of scale referred to in the conclusion.
Unambiguous terminology is a prerequisite for any fair debate. In addition to its importance for science and technology, the clarification of terminology is of great political relevance. Most importantly, however, such clarification serves to facilitate the debate between these realms.

1.5 The art of questioning

Questions of possibility in terms of probability

Despite the little effort required to bring design and policy into line with each other, it is only with great effort that a technical attitude can be combined with an empirical or theoretical perspective. Antagonism exists between craftsmanship and research, as experienced by any designer in the process of collecting data for design. The more data you collect, the fewer liberties remain for the design. Conversely, the more creative designers may be, the less interest they are likely to demonstrate in facts. Such antagonism reflects the contrast between a projective and a retrospective attitude, between an expressive and an impressive character or between a holistic, spontaneous, conditional approach and an analytic, causal approach. Such antagonism may be responsible for the generally accepted division of tasks between the two sides. They are related to each other in the same way that inhaling is related to exhaling. Although both are necessary, they are always at odds with each other.

Synthesis and analysis

One possible consequence of this dichotomy is a breakdown in communication or even a controversy between designers and researchers. Designers may be of the conviction that the increasing specialisations of empirical research impose an intolerable restriction to the integral field of vision required for design. Spatial designers must cope with the totality of a physical, biological and human reality, in addition to a constantly shifting context of space, time, ecology, technology, economy, culture and management. On the other hand, researchers may be convinced that the restrictions of scientific disciplines offer the only way to avoid the danger of unfounded, muddleheaded or 'all-encompassing' speculations. Without a doubt, many difficulties could be resolved if designers were able to ask only clear and unambiguous questions – but this is seldom the case. In a design process, it is hardly ever the case that a single problem must be resolved at any given time. The design process is more likely to entail a *field* of problems that involves many stakeholders and that changes both during and through the actual process of sketching. Moreover, most educational programmes in design place less emphasis on cultivating the ability to formulate problems and questions than they do on cultivating the ability to produce possible solutions, concepts and pictures – in other words, on cultivating answers.

The art of asking questions about nameless gaps

Asking questions in such a way that you receive the answer you need is an art that requires extensive education. After all, the ability to ask questions requires the ability to recognise *gaps* in either personal or more general knowledge. You cannot see the emptiness of these gaps and then identify it as an object (Meno's paradox[a]). The awareness of nameless gaps is a very difficult task in and of itself. It is thus necessary to approach gaps from the outside. The awareness of gaps cannot originate from within any single black centre. Such awareness assumes a certain measure of holism, an overview from which the emptiness can be felt (e.g. in the act of designing). It is thus even more difficult to describe or circumscribe the recognised gap clearly and in scientifically understandable terms, simply *by virtue of the fact* that it is a void. In order to ask a question, you must already have some level of awareness regarding the unknown and its boundaries. For this reason, the more you know, the more you become aware of what you do not know. It is as if you are walking over an iron grating as if it were a solid floor; while looking down, the surface appears to consist primarily of gaps.

[a] Plato (380BC) *Laches Protagoras Meno Euthydemus* (Cambridge Massachusetts 2006) Harvard University Press Loeb Classical Library series page 299

Founding design decisions on soft grounds
Designers often feel an urge to found their design decisions, but they usually cannot formulate the voids of their knowledge in a scientific manner. In many cases, this drives designers towards a dilettantish and speculative type of theory that attracts little more than ridicule within a scientific context. Nonetheless, such reactions from the empirical-scientific side are no more justified than are the designer's feelings of being fooled by partial, general or obvious truths that do not fit within the governmental, managerial, cultural, economic, technical, ecological or spatial context at hand.

Studying vague questions an ill-formed problems
Empirical scientists would do better to consider the constructions that designers develop in order to justify their design decisions in a scientific manner, in the attempt to answer questions that they obviously cannot formulate and for which science evidently still has no answer or even terminology. To understand this situation, you must step down to the most fundamental designing act of any designer (not only of architects or urbanists, but of mechanical engineers and other types of designers as well): separating and connecting.
On paper or on a computer screen, this design act is expressed through lines that somehow represent a realisable separation or connection (together called selectors if they occur paradoxically at the same time but in different directions; see *Fig. 8*). The form and function of these selectors within a spatial context are so complex that they cause designers to fall back on mystifications in order to justify their designs.

Convincing by form
For example, suppose that an architect draws a line representing a separation between the 'inside' and the 'outside'. Perhaps you have experienced the semi-poetic, tangled, associative and scientifically nonsensical speculation that architects usually develop with regard to the 'inside' and the 'outside' in order to justify the course of the lines that have been drawn. Within the context of such speculation, the 'outside' becomes preferably enclosed by the 'inside' in such a way as to bring the public area (and thus the whole of human society and the universe) inside the seclusion of the personal, the familiar and the domestic. At the same time, this intimacy exposes itself in the non-personal – the 'outside' – such that the humans involved feel guided through the field of tension between the private and the public by the forward pressure towards the 'inside' – the safe, dry, warm singular individuality, and the process continues. The discourse is often clarified by vertical, horizontal and circular movements of the arms and hands intended to transform the audience into speechless insiders (and thus silent accomplices) within an ultimate truth.

What, how, why questions
In my opinion, therefore, merely brushing aside such an architect's story as nonsensical does not demonstrate a scientific attitude. Such an attitude should involve questioning the questions that the designer is attempting to answer. The answers given by the architect that should be of less interest to you than the unspoken questions from which they originate. These questions are apparently so burning that they justify such a story.
Proceeding from the assumption that connecting and separating is the essence of any design, these questions can be analysed in three categories:

- *What* exactly is it that I am separating (e.g. cold from warm, dry from wet, safe from unsafe, public space from private space), or what am I connecting? In more formal terms, which environmental variables are varying here, in which direction and by which values?
- *How* can I separate the different environments (e.g. straight, curved, in several stages or kinds for each variable; sharp or vague, discrete or continuous, complete or incomplete, by material or by distance)?
- *Why* should I separate these values of imaginary variables and not between those of other variables? Why should I separate them in this way and not in another way? Why should I want to separate these two environments at all?

Contradictory answers from different directions

Science obviously has answers for many of these questions. If you ask a specialist in physics, the answer may be that you are separating between dry and wet or between warm and cold and that you can separate them most economically by a sphere. These answers nonetheless leave the ‘why’ question open. A biologist may be able to address variables of safety and use for the survival of an organism, while a specialist in the humanities would be likely to refer the designer to a psychologist for the private area, to a sociologist for the public area, to a geographer and an economist for their particular subjects, and so on. Each of these specialists would provide different or even contradictory answers. Specialists provide few arguments to balance them in a line between the ‘inside’ and the ‘outside’. Given that many lines must be drawn in a design, it is perhaps more attractive simply to draw them, simply to make a design devoting all that much attention to the paralysing question of, ‘Why this way?’ Once the lines have been drawn and the design is ready, science and the humanities can address the consequences and conduct impact analyses. This is too late for the designer, however, who can learn only from the disapproval of various disciplines with regard to earlier designs. For this reason, experienced designers often cease to see the problem and thus teach their students as if there is no problem.

A grid of hypotheses

This study aims to be relevant for designers while being understandable to empirical researchers as well. It attempts to formulate the questions that a designer should ask. It attempts to cover the area of desired knowledge with a grid of hypotheses upon which you can walk, even though looking down provides a view of an overwhelming number of gaps. The grid actually consists primarily of gaps, filled in sporadically by existing empirical matter. Where the gaps are larger, you must be cautious. These gaps reflect areas for which science and the humanities do not provide any definitive answer. This grid (or network) of hypotheses is intended to provide a grasp of the totality of problems with which spatial planning and design must cope from the perspective of environmental diversification. It is also intended to raise awareness of the gaps and to make them explicit. Many gaps may have become localised by the terminology offered here and formulated as questions that have remained unanswered for so long that we have forgotten to ask them.

Answers to the preceding questions

This study attempts to analyse some of the answers that designers offer, along with their implicit choices and tacit assumptions. These answers should be unfolded in such a way that they can be transferred from handicraft into explicit and questionable assumptions. Some may be transferred into empirically verified propositions. The implicit choices and assumptions of design, however, constitute only a small part of a much larger range of assumptions about possibitity. This may subsequently result in a much greater area to be explored. Moreover, the possibilities that extend beyond the most probable futures we face are more necessary now than they have ever been before. The ecological crisis is raising questions that force us to find new solutions. The boring habit of reproduction, copying and combining should be replaced by true mutations, thus demonstrating true creativity.

Uncovering implicit suppositions

In many cases, however, the transition from implicit to explicit assumptions is a painful process. The usual imaginations, which are broadly shared with many other people, may unfold into contradictory assumptions. You may be forced to leave the familiar and safe imaginations that have thus far proved so profitable, because you shared them with your clients. Nevertheless, history contains an abundance of examples with which to prove that the wisdom of the crowd is not always that wise. In this study, I am painfully aware that I am part of this set of shared tacit assumptions known as ‘culture’. You cannot explain to a fish what water is until it is drawn out of the water. Although this text may contain many hidden assumptions, I can at least try to make some progress.

The sequence of questions

The overall structure of the study is determined by the questions addressed the previous paragraph: ‘What’, ‘How’, ‘Why’. The parts of the study answers these questions approximately as follows:

What varies in our environment?

- A catalogue of environmental variables (Chapter 3)
- Morphological diversification (Chapter 4)

How could our environment diversify?

- Morphological diversification (Chapter 4)
- Structural diversification (Chapter 5)
- Functional diversification (Chapter 6)

Why should our environment diversify?

- Functional diversification (Chapter 6)
- Desirability of diversification (Chapter 7)

Shouldn’t it be the other way around?

You may wonder why the desirability of environmental diversification is not addressed in the first section. Shouldn’t I first explain why our environment should differentiate at all before I begin to address questions concerning what must be differentated and how this can be achieved? At this point, we directly touch upon the priority of this thesis. The objectives are primarily technical and oriented towards design, accompanied by a scientific, empirical-theoretical objective and the objective to be useful for politics and decision-making. Designers, who are preoccupied with means and possibilities, first seek to show what the possibilities are before offering choices to their clients. Social scientists, who are preoccupied with values, aims and expectations, seek to formulate the desirabilities and problems first, before listing the possibilities for a solution.

Choice assumes alternatives

From the perspective of design and technology, I follow the argumentation that you must first be aware of the alternatives and their consequences before you can choose. You must first know what environmental diversification can be, before you can choose for any of its manifestations. A simple definition cannot raise an image of all forms in which environmental diversification can appear. That requires a number of chapters. The chosen sequence thus has the important didactic and logical side effect of increasing complexity and decreasing possibility to verify. The content of theoretical constructions and the premises necessary in order to make any progress are likely to increase in the course of the argument.

Variables and their values

The catalogue of environmental variables has nearly no theoretical background. The choice of variables and their values (and the way I bound them to scale alone) can be disputed without much reference beyond that which you can observe everywhere. In this section, therefore, I do not attempt to provide a closed scheme in order to avoid all gaps and overlaps. On the contrary, the reader is challenged to find more than what I could do in the allotted time.

Form, different ways to distribute them in space
The section about morphological diversification subsequently assumes the existence of environmental variables (e.g. those that have appeared in the catalogue), along with their scale-bound character. The section then adds the assumption that each form can be localised at a scale of morphological diversification between the extremes of total accumulation and total sprawl.

Structure, different ways to stabilise them
Structural diversification thus assumes these pronouncements about content and form in the elaboration of the subject, as presented here, although it does not pretend that this is the only possible way. These pronouncements represent one of the possible elaborations, thus demonstrating that elaboration is indeed possible, even though it is one of the few that ever to have been elaborated at all. This elaboration thus has specific premises, but you need not accept these particular assumptions in order to understand that the development of functional diversification in the following section requires a concept of structure.

Function, different ways to use them
Some concept of structure and structural diversification (whether tacit or not) must necessarily precede any concept of function and functional diversification. The concept of function thus also contains hidden assumptions regarding form and content, although they need not be the ones I present here.
The section about functional diversification introduces ‘humankind’ into the argument. It is restricted to the diversity of functions that different environments may have for humankind and society. It is thus necessary to assume that these environments do have structure, form and content. If you accept this assumption, this section will be necessarily more complex than the previous sections.

Intention, different ways to judge them as desirable
Desirability thus supposes that environmental diversification serves some function for humankind and for society. It is impossible to discuss the desirability of environmental diversification until you have sketched an image of all forms by which the concept of environmental diversification may acquire a meaning. This image need not be complete. In this study, it is also far from complete. The exploration of its meanings with regard to content, form, structure and function, however, establishes the outlines by which the desirability of environmental diversification *at least* should be discussed.

Producing choice
In discussing the desirability of environmental diversification, I am skating on very thin ice. The preparation of a choice includes the design of alternatives, although this implies a choice amongst alternatives existing within a multitude of possibilities. Their evaluation is only partly empirical. Multi-criteria decision analysis can help inform choices between variables, as long as there are not too many criteria and as long as their values can be weighted. If these conditions are not met (which is usually the case), this form of analysis merely prepares the choice by raising awareness of the alternatives and their values; in the end, choosing will replace knowing.
The values themselves may have technical and scientific aspects. Some values of diversity (e.g. perceptual or theoretical values) can be underpinned and verified through empirical research. Other aspects (e.g. balancing the desirable against the possible and estimating the associated costs) require technical expertise and calculations.
In principle, therefore, the utility of all of the objectives of this study is manifest in answering the question: ‘Why should our environment differentiate?’ This question is also the most complex and final question. Nevertheless, it remains unanswered. If it could be answered, then there would be no choice.

Method used for selecting the variables

The first question ('What varies in our environment?') has hardly any political or technical implications. Although its answer may appear to be an empirical exercise, I have my doubts. For this exercise, I collected hundreds of Dutch topographical maps, copied pieces of 10cmx10cm with radiuses of R=300km, 100km, 30km, 10km, 3km, 1km, 300m and 100m at the appropriate scale and pasted them into eight albums, according to radius. I then took a compass to each album, with distances of 300km, 100km, 30km and so forth between the legs. On every page, I closed my eyes and placed the compass blindly on the map. I then opened my eyes, each time asking myself, 'What is the difference of the environments around the point at which the legs came down? Is it characteristic for that level of scale? Could it be influenced by design? How should I identify these environments as values of a variable or as legend units for design? How should I identify the variable containing both values? Can I imagine a zero point of the variable?' This exercise was an attempt to avoid hidden assumptions, with the goal of being as objective and empirical as possible. Whether this goal was met is open to question. I assumed that scale matters. I assumed that the maps represented a reality that I could imagine at that level. I assumed that my imagination bore some resemblance to reality, and so on. At any rate, the exercise resulted in the awareness that the choice of variables for studying diversity cannot be anything other than accidental. It could be argued, however, that this is the case with any empirical research.

Doubts regarding the ultimate possibility of rational choice

The methods of empirical research contain many rules and restrictions, as known from methodology books. You should have a well-formulated problem, an aim, starting points, proper statistical instruments and so on, but the choice of a research hypothesis should be free.[a] My experience suggests that the choice of variables should be free as well. Many variables are chosen implicitly by custom, and they are no longer disputed within the discipline. Physics has mass, time and length, while sociology has age, gender and income. The problem (e.g. criminality) raises new variables (e.g. number of robberies), and these new variables are immediately related or reduced to the well-known variables (e.g. age, gender, income). Although this process is experienced as natural, custom is essentially accidental. Even if the variables and their values are selected according to a criterion of observability, they remain accidentally chosen by the reach of the human senses and the available instruments to expand their reach. I am even more concerned by the fact that the measurements, relations and conclusions are reported in a language that may bear hidden assumptions in the prefabricated categories of common words or legend units. In this study, I leave these concerns for future research.

The question of relevance and completeness

How can you decide whether the accidentally chosen variables are appropriate for describing and explaining environmental diversification? How can you decide whether they are sufficient in order to find the relationships that are relevant for future design?
In this thesis, I resolved these issues simply by distinguishing as many variables as I could imagine, accepting that many would overlap and that many more could be found or proposed. I decided not to bother about their possible overlaps – that would be a concern for later. Upon studying their relationships, the overlaps (and consequently double counting) or truisms would appear. This would allow anyone to reject some variables and propose others. This could be accomplished through empirical research aimed at discovering which relationships actually exist, or by design study aimed at identifying which relationships may be possible. In design study, the choice of variables is largely restricted to those that can vary in space (a relationship with length). If they cannot be related to space, I assume that they are not relevant for spatial design. This restriction was already hidden in the method used for finding the variables, as described above and as further elaborated in Chapter 3.

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[a] Groot(1961) Methodologie: grondslagen van onderzoek en denken in de gedragswetenschappen (Den Haag) Mouton & Co

After 'what' comes 'how'
Design-related studies should thus result in 'how' questions, which are not aimed at discovering how variables and their values *are* related, but at inventing how they *can be* related. The current study formulates these questions in Chapter 4 (morphological diversification) with regard to the relationship of the variables and their values to space in terms of distribution. In Chapter 5 (structural diversification), these questions concern the relationship of the variables and their values to construction in terms of 'selection'. Structure is thus defined as the set of separations and connections. Any combination of separation and connection is called a 'selector' (see *Fig. 8* and *Fig. 9*). Selectors influence and stabilise the values of environmental variables in space. They stabilise a difference that would not exist without them. For example, a window is a selector – a kind of sieve. It separates temperature, and it connects light, thus conditioning a stabilised difference. This implies that a different relationship remains between the two variables. In Chapter 5, several possible connections between the variables and their values are discussed at different levels of scale.

The 'how' question is the core of design
Given the priority assigned to design and technique, the 'how'-question forms the core of this study. The answers – the investigation of structural aspects of environmental diversification, flanked by their morphological conditions and functional consequences – are of primary relevance to designers. In this argument, the designer is no longer considered exclusively as the provider of form or function (if such has ever been the case), but primarily as the provider of structure. The designer is thus the one who knows and varies openness and seclusion in all of their meanings and at different levels of scale. The designer is the one who conditions isolation and communication in all of their spatial manifestations, who constructs separations and connections, static and dynamic spaces, residential places and spaces for movement, shells and networks. Structure is thus the means by which a designer influences function and form without determining them. This can be accomplished only if the concept of structure has been elaborated with substantial and applicable content, with an equivalent position between form and function. This study aims to provide a modest contribution.

Preceding and following chapters
The five parts of the study may now be recognised in the terms of content, form, structure, function and intention, preceded by chapters containing problem statements and methodological accounts. The study is followed by a conclusion addressing several aspects of its applicability, a summary, a list of literature (with several remarks) and a list of key words with several definitions.

2 Questions, limits, problems, aims

2.1 The origin of the question

Increasing population and space/inhabitant

After substantial migration from rural areas into the cities in the 19th century, the urbanised area of the Netherlands increased in the 20th century due to the explosive growth of the country's population (from 5 to 16 million) and then, even more importantly, to the increasing urban area required for each inhabitant. Since the Second World War, the average number of people living in a dwelling decreased from 5 to 2. The shortage of dwellings directly after the war resulted in an unprecedented level of building activity and the proliferation of rapidly built homogeneous suburbs in more spacious settings. The exploding number of cars demanded additional public space. The booming 1960s required even more urban space per inhabitant, in order to realise greenery and new facilities.

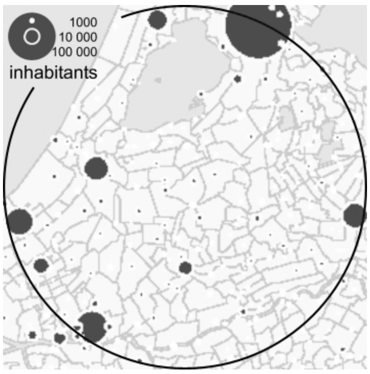

Fig. 11 A.D. 1800

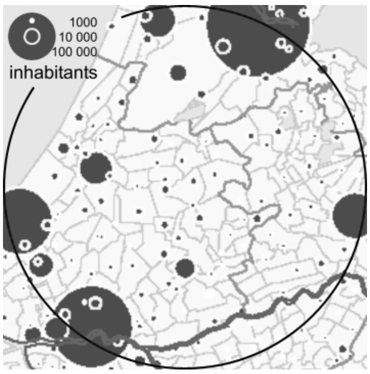

Fig. 12 A.D. 1900

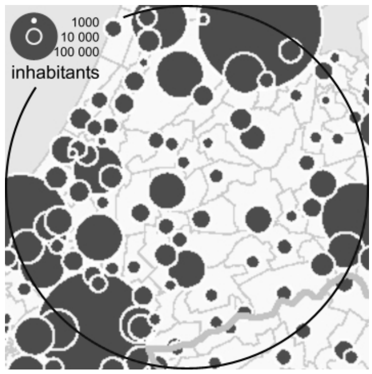

Fig. 13 A.D.2000

Population Randstad R=30km[a]

National Policy Documents on Spatial Planning

The First National Policy Document on Spatial Planning in the Netherlands was adopted in 1958.[a] This plan proposed to avoid additional sprawl by concentrating urbanisation in a ring R = 30km around an open Green Heart, in addition to outward de-concentration to new towns. Since that time, people began to demand additional diversity in residential environments, as well as more choice for themselves and for their children. The concept of 'environmental diversification' was therefore included in The Second National Policy Document on Spatial Planning, which was adopted in 1966.[b] This plan was represented in the form of a map comprising life-sized blocks (see *Fig. 14*).

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[a] © Ekamper(2007)Bevolkingsatlas van Nederland(Den Haag)NIDI http://www.nidi.nl

[b] VROM(1966) *Tweede Nota Ruimtelijke Ordening* (Den Haag) Staatsuitgeverij http://www.canonro.nl/de_Canonro_nl/Leestafel/Nat__plannen/index.aspx

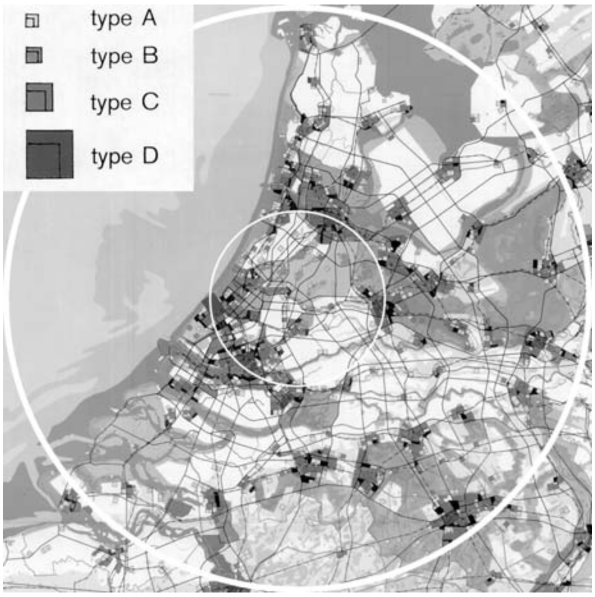

Fig. 14 Blocks map 1966 for 2000[c] R=100km

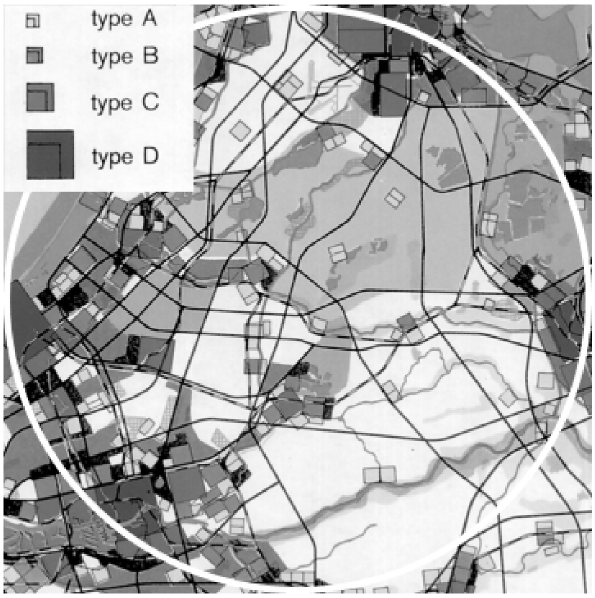

Fig. 15 Detail Fig. 14 radius R=30km[a]

Although this plan is now concerned a milestone in Dutch urban planning and regional design,[b] we no longer share its optimism with regard to the possibility of centralised spatial planning and design. The map was made by the design department of the Ministry of Spatial Planning, based on the expectation that it should provide housing for 20 million inhabitants by 2000. The Ministry's research department quickly deemed this projection too high. The research department then took the initiative for developing a third national plan[c], but these efforts eventually failed due to an overload of research reports and a lack of a clear concept. The fourth national plan (VINEX) once again proposed concentration in 'compact cities'.[d] This plan resulted in a multitude of 'VINEX districts', which soon drew criticism for their excessively diverse, chaotic appearance and their failure to realise sufficient density to avoid sprawl to any substantial degree. The last (fifth) national plan accepted more sprawl, but it was never adopted.[e] The Ministry of Spatial Planning was assumed into the Ministry of Infrastructure and the Environment, assigning additional responsibility for spatial development to the regional and local authorities.

Design realised with a different content

If you you compare *Fig. 12* with *Fig. 13*, then you should admit that the design of *Fig. 14* largely covers the current reality. The over-estimated population has been compensated by an unforeseen increase in urban land use per inhabitant, thus generating a similar picture. Upon closer examination, however, the intention of environmental diversification is less recognisable. For areas in which prosperity is still expected to increase, however, diversification is more pressing than ever. Without sufficient diversity from which to choose, the increasing prosperity becomes prosperity without choice. In the 1960s, the younger 'alternative' people were looking for 'alternatives'. They were populating the Ministry during my residency to study environmental diversification.

The concept of Environmental diversification

'Environmental diversification' originally referred to the development of residential areas with increasing diversity in terms of density, size and level of facilities (Environments A, B, C and

[a] VROM(1966) *Tweede Nota Ruimtelijke Ordening* (Den Haag) Staatsuitgeverij
[b] http://www.canonro.nl
[c] VROM(1977) *Derde Nota Ruimtelijke Ordening. Verstedelijkingsnota* (The Hague)RPD
[d] VROM(1992) *Vierde nota over de ruimtelijke ordening Extra* (Den Haag) RijksPlanologische Dienst
[e] VROM(2001) *Ruimte maken, Ruimte delen, Vijfde nota over de Ruimtelijke Ordening 2000/2020* (Den Haag)Rijksplanologische Dienst

D; see *Fig. 15*). Its meaning, however, was soon extended into other levels of scale and other categories. It was concerned applicable to 'the entire range of transitions in the urban and rural area'.[a] During the development of the third national plan,[b] it appeared as the second basic aim of national spatial planning: 'The stimulation of spatial and ecological conditions in order to guarantee as much diversity, coherence and sustainability of the physical environment as possible'. In this context, the term 'sustainability' appeared a decade before Brundtland[c] advocated it (with a global impact) in order to preserve freedom of choice for future generations. In Brundtland's case, however, the concept of sustainability was directly connected to environmental diversity.

Diversity as a condition for choice

Instead of aspiring to achieve one 'best' solution for spatial planning and design everywhere, environmental diversity was recognised as a necessary condition for choice. In addition to offering choice for future generations, it offers choices to the present inhabitants (Environments A, B, C and D), with their different stages in the life cycle, different income groups and different life styles.[d] Instead of prescribing a single 'best' quality, this national strategy stimulated a variety of qualities. It also offered choices for lower levels of administration. It allowed for differences between regions, municipalities or neighbourhoods.
The documents preceding the third national plan elaborated the main aim into partial aims. The concept of environmental diversification was explicitly declared applicable at four different levels of scale: national, provincial, urban regional and local. The natural environment was finally mentioned as an area of application: the stimulation of diversity in ecological systems. When concentrating the urban built-up area, the plan called for open buffer zones between urban zones in order to realise a kind of environmental diversification with nature close to home.

Failing control

In the years that followed, the emphasis on environmental diversification faded. The intended strategy failed due to a lack of political instruments. Control systems are uniform by nature; they tend to generalise instead of differentiating. If this is the case, you would do better to avoid control systems and leave the diversification to private initiatives. I have my doubts, however, given that diversity at the lowest level of scale may cause homogeneity at the other levels. Moreover, globalisation has increased the power of corporations to a level that matches that of governments. You can recognise them in any shopping centre in any neighbourhood, anywhere in the world. You can no longer escape this homogeneity through travel.
The subject of this treatise is thus not aimed at finding administrative instruments for environmental diversification. The concept itself must first be clarified.

Urban and rural environments

The origin of the question was based on the range of environments between urban and rural areas. It has now become popular, however, to suppose that there is no longer any distinction between urban and rural areas. Nowadays, any rural area in the Netherlands has been urbanised. The term 'urbanised', however, depends upon the level of scale and the associated variables that you take into account. To say that the entire world is urbanised is to strip the word 'urbanisation' of all meaning. There are differences in urbanisation, regardless of whether any purely natural zero point exists for that variable.

Many variables involved

In most cases, towns of different sizes have differing levels of amenities, a different

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[a] RPD(1971)*Publicatie 2*(The Hague)RijksPlanologische Dienst
[b] VROM(1974) *Nota van Wijzigen op de Oriënteringsnota* ('s-Gravenhage) Staatsuitgeverij
[c] Brundtland(1987) *Our Common Future* (New York)UN
[d] Michelson(1970) *Man and his urban environment: a sociological approach* (Menlo Park, California) Addison-Wesley Publishing Company, Inc. Philippines

relationship to the surrounding countryside and a different relationship to other towns. They consequently offer different living environments and attract different ages, income groups and life styles. Since 1967, the Dutch national strategy for providing such different living conditions has been known as 'environmental diversification'. This strategy was soon applied at other levels of scale and spatial categories as well. Its study was intended to clarify the meanings of the term and its consequences.

Variables of different order

The *content* of the relationship between urban and rural areas may be determined by variables of the first order (e.g. the range from culture to nature, the amount of built and vacant surface, high and low densities of inhabitants, employees and facilities). Any of these variables may produce different patterns applied at different levels of scale. *Form* may be expressed in values of dispersion between accumulation and spread at different levels of scale, as the term 'bundled de-concentration' apparently indicates. Bundled de-concentration was part of the above-mentioned strategy of 'environmental diversification'. It was intended to concentrate within a radius of 30km, while de-concentrating within a radius of 10km. *Structure* arranges different values of isolation and accessibility (a third-order variable) across larger and smaller towns and their inhabitants. These different kinds of isolation or connectedness attract different *Functions* (fourth order) are attracted by within that structural diversification. This relationship is not deterministic or causal, but conditional. Although agriculture in the city and industry in the country are still possible, they are limited. *Intentions* (fifth order) may change the distinction between town and country, but they are motivated by functions and conditioned by the existing functional diversification.

Variables applicable inside and outside urban areas

This example of differences between urban and rural environments clarifies how the parts of this study can be applied to the distinction between town and country, within the desired of applicability at any distinction within or outside the city. Most of the examples provided in this study stem from urban areas. This is not because the developed terminology would be not applicable to rural areas or intermediate areas. It is because of the complexity of urban areas, in which the full extent of environmental diversification may be shown.

More contrasting values by human impact

The distinction between diversification of content, form, structure, function and intention in this study is inspired by the fields of biology and ecology. Its application to agricultural and natural areas is even more obvious than its application to urban areas. A natural landscape provides an even better example of how environmental variables may vary over a characteristic distance, with fewer contrasting values maintained by fewer sharp separations. Gradual transitions show more diversity of plants and animals than do sharp boundaries.

Ecology

For ecology, the relevance of this study with regard to the concept of 'content' may lie in the suggestion to pay more attention to the scale of environmental variables and to their dispersion in space, their structure and their function. Scale articulation might simplify and deepen the analysis of ecological systems. It might even disclose new areas for ecological research. The natural landscape also comprises many variables (wet/dry, acid/base, flat/hilly), as well as the associated phenomena of accumulation and spread of their values, including all forms and shapes in between. This applies to the presence of different species as well as to the values of environmental variables. The form of the landscape is determined by different dispersions of different elements. In addition to *form*, a natural landscape also reveals an ecological *structure* –i a set of separations and connections, barriers and rivers, gradients of sensoric or motoric accessibility. These separations and connections (selectors) have different meanings for different plants and animals. They are therefore selective in different ways for different organisms (e.g. insects, mammals or birds). They consequently

differentiate between closed and open ecological communities of species. The gradients between open and closed areas may be represented as environmental polarities to be arranged in a way that is characteristic of each landscape.
Finally, the natural landscape has a diversity of functions for any accidental organism, including humans. Conversely, any organism has a different function for the landscape. In this case as well, the concept of 'function' has two opposite meanings: the outward function of parts for the whole and the inward function of the whole for its parts. As in this anthropocentric study, it is thus possible to distinguish different kinds of function.

Urban landscapes

The distinction between content, form, structure, function and even intention can thus be applied to both cultural and natural landscapes. In this study, however, it is elaborated primarily for urban landscapes. With regard to the intention of environmental diversification, humans and human society are central in this study. The natural landscape is thus addressed only within the context of its potential functions for humans and society. Because the study concerns design, it is primarily anthropocentric.

Subsequent questions

The multitude of levels and categories to which the concept of environmental diversification can be applied to urban and rural environments raises several questions:

a. Are there other conceivable meanings for the term 'environmental diversification'? Are there other fields of application possible? How are they connected to each other?
b. Which environmental variables can help to provide a more scientific grasp of the phenomenon? Which values do these variables take in reality, and which other values might still be possible? How are they bound to levels of scale? What is their relationship at and between various levels of scale? How may their values be combined into new types of environment that could be applied in design?
c. Could environmental diversification at one level of scale obstruct diversification at other levels? For example, could national diversification cause regional homogeneity? To what extent is it thus possible to extrapolate conclusions at one level of scale to other levels? For example, if you decide that residential, industrial, recreational and traffic environments interfere with each other and that they must be separated, is the municipal level the appropriate level at which to realise this kind of environmental diversification? Could this be called scale falsification? If you aim to achieve freedom of choice for the users, is it necessary to apply the diversification of environments (represented in the legend units of your drawing) at the appropriate level of scale? When does it become falsification?
d. Can other aims from spatial planning and design be reduced to environmental diversification? For example, is the concept of bundled de-concentration a kind of environmental diversification? How are accumulation, spread and similar phenomena related to environmental diversification?

Questions such as these require a fundamental inquiry into the concept of environmental diversification in all of its manifestations. It requires locating them in relation to each other, determining whether they tolerate each other and investigating whether mutual reinforcement or obstruction could be context-sensitive. In formulating a study that could answer this kind of questions, my primary task is to define the concept of environmental diversification in more detail. I can attempt to create an overview of the entire conceivable field of study in order to select the appropriate limitations for a statement of the aims and problems.

2.2 Limits of definition

Defining diversity and environment

In this study, environmental diversification refers to the development of additional diversity in the environments of people, or to the results of such development.
The terms ‘diversity’ and ‘environment’ thus require closer investigation.

Diversity

First, we should distinguish at least two kinds of diversity: morphological and functional. This distinction is necessary, as they do not always go together. For example, the proper maintenance of monuments in a mediaeval inner city may retain its morphological diversity, although its functional diversity could decrease if only offices and shops remain. Conversely, an increase in different activities and ways of use can create a homogeneous appearance within the multi-functional environment. The connection between form and function is a classical question in design theory (‘form follows function’). This study demonstrates that a third kind of diversity is needed in order to solve this question: structural diversification. Let us leave this and other the distinctions aside for a moment. Functional diversification assumes a diversity of collectively accepted use. Morphological diversity assumes a locally different composition of variables operational in each environment (i.e. content, as in material or colour) and the different dispersion of their values in space (i.e. form). To be precise, you should distinguish this into a diversity of content and form. For the time being, however, it is sufficient to be aware that there are different orders of diversity.

Environment

The term ‘environment’ deserves elaboration as well, given that it introduces an unlimited factor to the definition of environmental diversification, even if we limit our attention to the environments of people. ‘The environments of people’ can refer to rooms, but also to towns. You may therefore encounter very different meanings when speaking about environmental diversification. Let us start with the usual definition of ‘environment’:

> the totality of factors from the surroundings of organisms that have an impact on life and living of these organisms.

This definition distinguishes ‘life and living’, as the ‘impact’ should not refer only to mere survival, but also to the different possible ways of living that are conditioned by an environment. You can immediately replace the vague term ‘from the surroundings’ with ‘within a given radius’. The definition then assumes a given radius before it becomes operational. In this study, therefore, the concept of ‘factors’ is used to refer to ‘variables and the variations in their values’ (within a given radius). This places diversity in a central position within the definition, and it provides a limitation to spatial diversity through the given radius. It is then possible to replace the term ‘organisms’ with the term ‘people’. In many respects, the argument may remain relevant for other organisms. Through this substitution, however, the term ‘have an impact’ should be replaced by ‘*can* have an impact’. After all, humans are able to change their environment by design and make use of variables that have previously had no impact (e.g. the presence of peat, coal, petrol or raw materials). This broadens the definition, although the other amendments have narrowed them.
The application of these substitutions yields the following definition of environment:

> the totality of spatial variables and their values, varying in a given radius around people that can have an impact on their life and living.

Environmental diversification

The ‘totality’ can differ from place to place within the environment, thus reflecting a diversity of places within that radius. in its turn, diversity can develop (‘diversify’), thus covering the core of the inquiry: environmental *diversification*.

However,

> if we will study environmental diversification at any different scale separately,
> if we select variables according to their relevant 'wavelength' at each scale,
> if we neglect other variables that may be operational at other levels of scale,

a difficult question remains.

For example, the climate and soil variables in our environment do have a different operational level of scale in space and time. The variation of the climate is a matter of hundreds of kilometres and millennia, while the diversity of the soil is a question of metres and centuries. The diversification of the soil is clearly connected to the history of climate. At different locations, the variables with a larger reach will cause other contexts for environmental diversification at the local level. In a different context, the impact of the chosen variables may become different. How can we derive any conclusion from such an argument that may be valid in locations other than those we took into account?

Possible diversification

The answer may be embarrassing; it is not the primary objective of this study. The primary objective is not to conduct empirical *research* but to sustain *design* and *technique*. Although it should be *understandable* to empirical researchers, I do not wish to make *predictions*; I would like to explore *possibilities*. I restrict my attention to variables that can be influenced by design, and the reach of design, execution and use in space is limited. I do not wish to explain the history and the inconceivable diversity of our environment by using generalisations that *reduce* it. I want to find means to preserve and to *produce* it.

Scale articulation

There may be an objection that is typical for designers: 'in designing you never stay at one level of scale; any designer should design through the scales!' Although I agree, in order to integrate them you must know what every distinguished level of scale means, what it does or what its possibilities are. Another question concerns how far we would like to go distinguishing levels of scale. Do we hope to design every molecule of the building? Will we take the whole universe into account when designing a building? The variables that may describe the 'content' of the environment do not vary at the same scale, in the same rhythm or in the same way. Their impact may be different at different levels of scale – even in an opposite manner. Heterogeneity at one level of scale becomes a homogeneous mixture at another level of scale. I referred to this phenomenon as a 'scale paradox' (see *Fig. 7* on page 21). It may result in the use of variables and their values (legend units) at the wrong level of scale. For example, recall the CIAM division in urban functions, as presented on page 12. If you use legend units from a different level scale, you may think that it is 'designing through the scales', but I would refer to it as scale falsification. From the perspective of environmental diversification, scale articulation is a crucial stage. It enables to obtain insight into the mutual relationships between different levels of scale. An important simplification and deepening of the analysis can be reached by first binding it strictly to spatial levels of scale and subsequently contrasting those stemming from different levels with each other in order to analyse the combinations. To do so, however, would require a combinatory explosion of studies that exceeds the scope of a study of this type.

Scale bound disciplines

I also considered binding the analysis to levels of scales in time. By doing so, however, I did not succeed in simplifying the analysis enough to maintain an overview. Moreover, scale articulation in space is more obvious in a study concerning spatial planning and design. The scale-articulated analysis of diversity may thus temporarily neglect variables that essentially belong to other responsibilities of our spatial organisation.

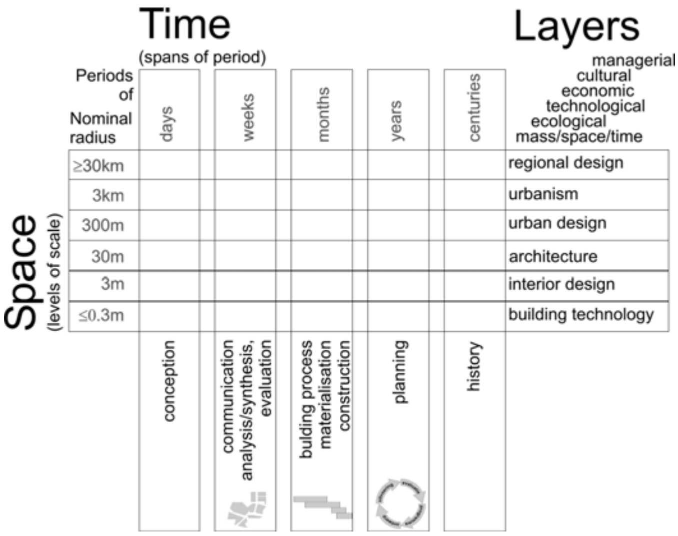

Fig. 16 Disciplines bounded in time and space

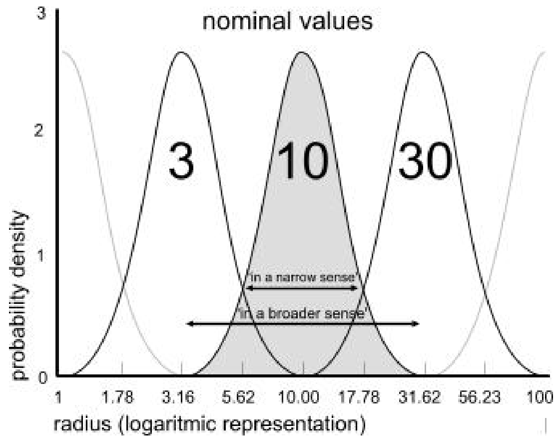

Fig. 17 Defining Nominal radius R

Scale	Nominal radius R	Nominal surface	10x10 cm Scale 1:	G-scale Hagget	Urban types (1966)	Potential urban form	Potential urban function
Micro	1m	3m²	20	14	a	spot	grip space
	3	30	60	13	b	place	room
	10	300	200	12	c	parcel	building
	30	3 000	600	11	d	block	building group
	100	30 000	2 000	10	e	allotment	ensemble
	300	300 000	6 000	9	A		neighbourhood
Macro	1km	3km²	20 000	8	B		district
	3	30	60 000	7	C	built-up	town
	10	300	200 000	6	D		conurbation
	30	3 000	600 000	5	E		urban region
	100	30 000	2 000 000	4	F		region
	300	300 000	6 000 000	3	G		land

Fig. 18 Twelve levels of scale

The levels of scale studied

In principle, therefore, I distinguish twelve different levels of scale. These levels need not have a functional meaning. Nevertheless, they do assign twelve different meanings to the concept of 'environment' (and thus to the concepts of environmental diversity and diversification). The twelve levels of scale are represented in *Fig. 18* by a number of characteristic numbers, codes and terms that are intended merely as indications or orientations. The semi-logarithmic series can be extended, if required. The nominal radius serves as a name for the level of scale of the intended environment. Its numerical value should be interpreted 'elastically', as a variable between the preceding and the following number in the series. For example, if I refer to a nominal measure by 'R=100m', I mean an environment with a radius between 30m and 300m (a diameter between 60m and 600m) or a surface between 0.3ha and 30ha (frame). In formal terms, '100m' is the average of a logarithmic probability distribution, with 30m and 300m as extremes. If you would like to make a 10x10cm picture or a map of the intended environment, the smallest appropriate proportional scales you could use are summarised. The average 'R=100m' can thus be depicted at 1:2000. This raises the question of resolution: What is the *smallest* subject that you take into account? If you take the elastic radius r of the largest circle or globe fitting in the smallest subject concerned as its nominal size (grain), the resolution is defined as r/R. In this study, this proportion between grain r and frame R will be 1%, the resolution of a normal drawing. A similar concept for the series of scales chosen here is the 'G scale', as introduced by Hagget (1965)[a]. It relates any scale to the total surface of the Earth (G-scale=0). The values presented here have been rounded off.

Agreement with usual urban categories

According to Hagget, this semi-logarithmic series is morphologically and functionally indifferent, at least in theory. These average measures, however, correspond surprisingly closely to the usual morphological and functional names presented in the last two columns. For example, if you draw circles around the surface of neighbourhoods, districts, towns and conurbations on the topographical map of the Netherlands, you will recognise the set of nominal radiuses R= {0.3, 1, 3, 10km}. The codes for environments in the previous column correspond to the Types A, B, C and D that were mentioned as a legend in the 1966 National Plan shown in *Fig. 15*. The series corresponds relatively well to the more functionally oriented series developed by Doxiadis[b], although this series has different intervals. These names have yet to be taken as informal examples of well-known forms and functions of similar size.

Every scale has its own legend units

The levels presented in *Fig. 18* divide the general concepts of environment, environmental diversity and diversification into twelve more specific meanings and contents. Their content can be represented by environmental variables, sorted according to the scale of their working. In other words, we can distinguish a room, a house, a property, an ensemble, a neighbourhood, a district, a town, a conurbation or an urban region with different variables or legend units, and consequently with the means of design. Some of these variables may have a range that is broader than that of just one of the distinguished levels. The design means may thus continue to differ. For example, if we take the variable of 'light', we can differentiate between light and dark in a room, a house, a larger building and its surroundings, perhaps in a neighbourhood, but less so in a district, town or other entity. At the highest levels of scale, however, it once again becomes responsible for the diversification of climate zones. Any environmental variable may thus be more applicable for design at some levels of scale than at others. Environmental diversification changes according to the level of scale through differences in the composition of variables.

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[a] Haggett (1965,1977) *Locational analysis in human geography* (London) Arnold

[b] Doxiadis(1968) *Ekistiks. An introduction to the Science of Human Settlements* (London) Hutchinson
Doxiadis(1970) *Ekistics, the Science of Human Settlements* (Science)1023 170 3956 p 393-404

2.3 Limits of scientific context

Questions

A comprehensive study of environmental diversification requires eight areas of study:

1 Related concepts of 'environmental diversification' in other disciplines
2 Exploring theories that may play a role in environmental diversification
3 The historical development of environmental diversification
4 Processes of levelling down the diversity of human environments
5 The desirability of environmental diversification
6 Environmental diversification in existing spatial plans and designs, study of legends
7 The variables of environmental diversification, their spatial appearance
8 Applied studies of environmental diversification

Limiting the question

This thesis is largely restricted to the seventh point (i.e. the variables of environmental diversification and their spatial appearance). In this case, 'appearance' includes the not necessarily visible separation and connection of the values of these variables. The other areas are raised only if they are relevant from this point of view. They are the context within which the subject is limited further. The following paragraphs provide a brief elaboration of this context, in order to clarify what is *not* studied in depth.

1 Not a study of environmental diversification in other disciplines

The concept of 'environmental diversification' has many relationships to well-known concepts in other disciplines (e.g. difference, heterogeneity, variation, variety, variables, change, alternation, specialisation, integration, dispersion and their opposites). Their connection to the environment opens up a connection to history, biology, environmental sciences and other fields. It also connects to such concepts as form, structure, function and intention, as used in many other disciplines and in daily parlance with their foundations in logic (modal or fuzzy) and philosophy[a]. These connections should be explored. Given that many disciplines are involved, however, we first need a trans-disciplinary vocabulary and method with which to explore these concepts systematically.

2 Not an overview of *theories* related to environmental diversification

Although you could develop an abstract system of logically related definitions in order to clarify the concept of environmental diversification, you could also seek a connection with existing theoretical conceptions from other sciences and the humanities. For example, the concept of inequality can be approached statistically.[b] In physics (particularly thermodynamics), many points of contact are available on this basis. In biology, 'diversification' or 'differentiation' is a key concept for understanding growth and form,[c] particularly in embryology and ecology, where it refers to sequences of succession.[d] Sociology has its notorious philosophers of diversification and specialisation[e], as well as the 'fathers of sociology'[f], who started their careers with 'diversification'. Even the functionalists[g] could not avoid the concept. Since its establishment, economics has been involved with the division of labour, specialisation and economic diversification as a condition for trade.[h]

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a Deleuze, G. (1994) *Difference and Repetition* (New York) Columbia University Press
b Lisman(1976)*Ongelijk, ongelijkmatig, onregelmatig en ongeregeld*(Economisch Statistische Berichten)1122 p907-914
c Arcy Thomson(1961) *On growth and form.* (Cambridge UK) Cambridge University Press
d Leeuwen(1966) *A Relation Theoretical Approach to Pattern and Process in Vegetation* (Wentia) **15 p**25-46
e Spencer(1897) *The principles of sociology* (New York 1929)
f Simmel(1890) *Ueber soziale Differenzierung, Soziologische und Psychologische Untersuchuchungen* (Leipzig)
Durkheim(1893) *De la division du travail social* (Paris 1967) Presses Universitaires de France
g Malinowski(1944) *A scientific Theory of Culture and other essays* (Oxford 1964) Oxford University Press
Radcliffe-Brown(1952) *Structure and function in primitive societies* (London)
Parsons(1966) *Societies : evolutionary and comparative perspectives* (Englewood Cliffs, N.J.) Prentice-Hall
Luhmann(1974) *Soziologische Aufklärung* (Opladen)
h Smith(1776) *An inquiry into the nature and causes of the wealth of nations* (London 1929)

3 Not a historical study of environmental diversification

You could clarify the meaning of environmental diversification from the perspective of evolution and history. In this case, however, it would be necessary to begin with the anthropological genesis by which humans developed limbs, a receptive system and the capacity to predict sequences.[a] You should then conclude from archaeological and ethnographic data how human settlements and houses have developed in interaction with the surrounding nature – how neolithic, industrial and other technological revolutions have had their impact. Finally, you would have to study the technical, political and economic history of humankind in order to get insight into the impact of class struggle, concepts of ownership, customary and written law and other factors on the diversity of environments.

4 Not a study of processes of levelling down

If you are worried about these developments, you should study the differentiating and levelling tendencies existing within an industrial-commercial society that you would probably wish to counteract. In addition to being historical in tone, such a study would have a technical, legislative and political character. You should make an inventory of the kinds of freedom that societies have gained and lost. The study should contain the influence of the explosive development of the money economy, mobility, communication, the use of materials, energy and information, their global exchange and their consequences in terms of the separation and combination of functions.

5 A limited attention for the desirability of environmental diversification

The motives for environmental diversification in and of itself constitute a vast area of study. They must be separated into motives that centre on the human as an endpoint of evolution and those that do not. The first group of motives takes ecological, economic, medical, psychological and philosophical considerations as a starting point, in order to demonstrate their utility for humans. The second system of motives proceeds largely from the natural development of 'ecosystem Earth'. It has to do with ethical obligations to a process of diversification and temporary stabilisation that caused and safeguard your very existence.

6 Not a study of existing spatial plans and designs, no study of legends

If your objective is to influence the diversity of environments, you should study the contemporary practice of policy, planning and design at different levels of scale, the variables that they may influence and the instruments that they use for this purpose. You should investigate which instruments and levels of scale are most effective, and whether other instruments and variables are still available. For example, you could study the usual legends of sector plans for agriculture, traffic, water management, energy supply, master-plans, as well as the more detailed integrated plans for towns, districts or neighbourhoods or other entities. You should study their interference – their mutual impact in order to gain an impression of their effects on the actual level of environmental diversification.

7 A study of design means

In addition to studying the concept of environmental diversification in relation to other disciplines, with regard to its logical structure, or as an historical, threatened, desired or consciously influenced phenomenon, you could study environmental diversification as a working of scale-sensitive environmental variables. You would then need to study the dispersion of the values of these variables in space, having locally different relationships to each other and different functions for humans. This kind of study would provide an active view of *possibilities*. It establishes a balance between science (or the humanities) and design (or technology). It establishes a balance between reflection and application, between past and future. It provides the greatest chance of relevance for policy and design, while remaining understandable to – and applicable in – science and the humanities.

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a Harrison;Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press

8 A limited study of applications

Finally, you could study environmental diversification through application. The question of environmental diversification plays a role in any question of spatial layout, whether hidden or explicit. It is important to determine this role and to determine what is possible and what is not. This type of study requires insight into the possibilities demonstrated by empirical research, promised by theory or assumed by imagination. It requires the capacity to make more differences than you could ever have imagined before now.

Limits of context

It may be clear that this study cannot cover all of these areas. I thus restrict my analysis to the part that promises a key position in the communication between science, technology and policy: Point 7. Even this restriction, however, opens up a vast field of study. It requires further limitation before I can formulate its aims and the problems that it attempts to solve. It requires the further limitation of ‘environment’, ‘scale’ and ‘diversification’ than was provided in Section 2.2. Exploring the limits of what *can* be done at all, unveils considerable knowledge about what *has* been done.

2.4 Limits of 'environment'

Combining your reduced impressions

Your environment provides you with an overwhelming flood of data that enters through all your senses – vision, hearing, smelling, tasting, touching, motion and perhaps others. You cannot be fully aware of all of the information you receive. An initial selection is already made for you by *distance*. The resolution of your senses reduces the information about remote objects as a background, which is less recognisable but more stable than nearby objects are when you move (parallax).

Memory

A second selection is made by *time*, through a memory that fades immediately and stores selectively. Actual impressions cover or refresh the selected memories of previous impressions as an ash rain over a landscape with bare peaks, valleys of mud and a layered soil. The steady peaks erode and the valleys are covered, but much is removed by rivers of oblivion. Old memories may be uncovered by the wind or through conscious digging. Most of these memories are merely fragments, however, sometimes combined in strange sequences and distorted objects in dreams or fantasies, or consciously reconstructed and properly dated. Underneath this landscape, however, sudden dark, unconscious movements or eruptions can lift some memories and depress others.

Sequence

This is the point at which the analogy to a landscape ends, because if there is no *change* of impressions, you will become bored and lose attention. If the impressions are already present, it is no longer necessary to store them anymore. *Change* arouses your attention. At some point, you start to select the changes themselves, storing them for comparison as patterns of sequence. That is a typically human activity.[a] You may refer to some elements of these sequences as cause and effect. I refer to the data combined with such assumed relations in time as 'experience'. This raises the question of how we learn to perceive our environment successively, assisted by increasing experience.

Imagination

The answer to this question should clarify how you may overcome the earlier reduction of impressions by distance. You have learned to imagine remote and larger environments than those you actually can observe. They are stored in categories other than those you distinguished within some direct environment at a younger age. The maps in an atlas show legend units that you cannot immediately observe in that environment.

Innocent perception

A study of child perception suggests that you have observed your first environment as an uncoordinated mixture of impressions. Your impressions of temperature, smell, taste, touch and noise changed dramatically at the time of your birth. Once you opened your eyes for the first time, a visual experience should have been added as a changing coloured mosaic, a *tableau mouvant*.[b] In the years that followed, this chaotic world gradually became understandable. What you can see is primarily flat, because your retina is flat, and the flat impression of your second eye is only slightly different. It is necessary to *construct* a third dimension by combining vision with other simultaneous impressions. Awareness of depth and the interpretation of stereoscopic view were probably initiated by new impressions of movement, combined with vision and touch. The beginning of 3D awareness may emerge as soon as some of the observed patterns can be touched and others cannot.

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[a] Harrison;Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press
[b] Piaget, J.; Inhelder, B. (1947) *La representation de l'espace chez l'enfant* (Paris) Presses universitaire de France

Pattern recognition

In the meantime, some pattern recognition may have been established based on the *difference* and *constancy* of objects. Identifying an object, determining its ‘identity’ is to observe ‘repeatedly the same’ (idem tidem, the etymology of ‘identity’). Recent studies of pattern recognition conducted with computers[a] indicate that differences of patterns in space must be recognised first (edge-construction) before their constancy (equality in time) can be concluded efficiently. In contrast, human pattern recognition is assisted by simultaneous information from our own movement and sense of touch. The miraculous synaesthetic synthesis of these completely different impressions of view, movement and touch into an awareness of separate objects in space must be learned. It is not self-evident that babies will recognise their mothers at a distance as being the same as their scope-filling mothers when they are close by (object constancy).

Identifying objects

It is natural to suppose that, for the first stage of pattern recognition, clearly different (coloured) and bounded objects in the direct environment (R=1m, grip-space) can help a child to distinguish or to identify objects (a primary condition or requirement for developing self-awareness, discovering your own boundaries and identity). The simple, clearly coloured and bounded drawings of Dick Bruna and or traffic signs illustrate this requirement for children and for rapidly moving or distracted adults. Complete homogeneity in the early environment has been suspected even as a cause of death for babies in an orphanage.[b] They died of boredom. The variables that generate the synaesthetically necessary diversity (e.g. colour, contour, movability, variations of hard and soft) are not always recognised by designers as means of design (i.e. as possible legend units in their drawings).

The radius of action

The size of an environment in which you can distinguish objects increases with age. Suppose that the environments you explored when you were 1, 3, 5, 7, 9 or 11 years old had a radius of approximately 1, 3, 10, 30, 100 or 300m, respectively. Which environmental variables at each of these levels may be important in order to become familiar with your environment, and which should play a role in designing them? This is not only a question of content or morphological (e.g. visual) diversity; it also involves structural and functional potential. The fundamental question of which kinds of difference are relevant for design has yet to be answered. Which variables can be varied at different levels of scale to provide sufficient opportunities for different people at different ages and with different lifestyles?

years old	**0**	**1**	**3**	**5**	**7**	**9**	**11**	**13**	
m Radius of frame	**1**	**3**	**10**	**30**	**100**	**300**	**1000**	**3000**	
Differences to experience:									**learning:**
hard|soft	x								danger
movable|non-movable	x								operational abilities
colour	x								recognition
windows|doors		x							orientation
light|dark		x							imagination
shelter|corners		x							to escape movements
function|time		x							every time its own place
visibility		x							hide-and-seek
accessibility			x						rules
control			x						other people
noise			x						context

[a] Pekalska (2005) Dissimilarity representations in pattern recognition (Delft) TUDthesis

[b] Spitz, R.A. (1945) Hospitalism: An inquiry into the genesis of psychiatric conditions in early childhood **IN** Psychoanalytic Study of the Child. Vol 1 (New York) International Universities Press p53-74

years old	0	1	3	5	7	9	11	13	
m Radius of frame	**1**	**3**	**10**	**30**	**100**	**300**	**1000**	**3000**	
Differences to experience:									**learning:**
temperature			x						kinds of clothes
wetness				x					hygiene
ceiling|shelter				x					in-betweens to hesitate
plantation				x					nature
sun				x					nature
formal-informal				x					different behaviour
recognition|suprise				x					initiative
run|compete					x				ambition
watch, learn					x				to learn
possibility to buy						x			expensiveness
~ to walk						x			interest
~ to ride a bike						x			ride
urban functions							x		exploration
meet|retire								x	projection|identification
atmospheres|cultures								x	identity

Fig. 19 Possible differences to experience at different ages and radiuses[a]

Fig. 19 shows a number of environmental differences that could potentially be useful for design as legend units. Their relationship with the age at which you probably became aware of these differences is nothing more than a guess. Although this could be a topic for further psychological research, it is not the ambition of this study. In the following section, I sometimes refer to this connection with ages with the sole purpose of making the treatise more accessible to your imagination.

Observing the natural environment

The horizontal differences in the soil largely reflect the *gradual* change of the chemical composition and granular size distribution of the soil. These differences consequently select gradually changing vegetation and the associated animal life. This is the physical basis of biodiversity. You are less likely to find sharp boundaries in nature. Sharp boundaries allow only two different environments. They often indicate a human impact. Vertically, there is a sharp boundary between ground and air, although this boundary is softened by stratification in the upper soil and by vegetation. For example, in a forest, many variables obtain intermediate values (e.g. moist, light, safety, stability, grip) according to the altitude. They offer different environments for different organisms according to their ecological tolerance(see Fig. 188 on page 218). A slope may also produce such gradual change from high and dry into low and wet. Further, any altitude line may show a different composition of species. Exposure to the sun in different wind directions adds gradual differences horizontally. In the natural environment, intermediate values cover the full range of the relevant variables more completely than they do in urban environments. In the urban environment, the many sharp boundaries and contrasts dominate the gradual differences through artificial separations and connections. The relevant variables thus do not reveal their values as easily in their theoretical sequence. Moreover, other environmental variables may be more relevant for humans than they are for plants and animals.

[a] Jong, T.M. de (2005) *Child perception* (Delft) Contribution ChildStreet Conference 26 August 2005

The advantage of a sequence with gradually changing values

The natural environment shows the advantage of gradually changing conditions over sharp boundaries. Gradually changing conditions generate greater biodiversity than do sharply bounded, homogeneous areas without intermediate values. This consequently provides better insurance for the survival of rare species. Our abilities of perception (i.e. vision, hearing, smelling, tasting, touching, motion) are developed in such an environment through evolution. For humans, a gradual sequence of changing conditions would provide more choice and consequently better insurance for spatial quality suited to different stages of experience, ages and lifestyles. Moving around, it offers you a natural balance between recognition and surprise, as intended in *Fig. 6*. The slow change of your environment as you walk or drive a car safeguards both recognition and surprise, and consequently attention. Homogeneous landscapes are boring, while environments that change too rapidly appear chaotic. It is neither easy nor efficient to *build* these intermediate values, however, and it is therefore expensive. Designers must explain more when they draw vague boundaries than they do when they draw clear-cut lines with clearly different, well-known environments on both sides. Clear lines reduce the number of legend units. Talking in well-known categories makes communication flow more smoothly. It saves time.

2.5 Limits of scale

Exploring possible differences

In this paragraph, I explore the kinds of diversity within different radiuses that we may know from our own experience and imagination ‘phenomenologically’. It does not pretend (or even intend) to be complete. It remains a sketch of the problem field. In the next chapters, we may be able to make these problems operational for design, research and policy.

In search for relevant variables at different levels of scale

Let us start to explore several examples at different levels of scale, recognisable by everyday perception, gradually adding experience from different contexts. Perhaps we can discover more values to fill ranges of relevant environmental variables. The more variables you could recognise, the more possibilities you could offer for spatial design. The challenge is thus to distinguish, recognise and identify these primary variables and their separate values as content, apart from the added variables of a higher order. Second-order variables thus concern the possible spatial distributions of the primary values of difference, while third-order variables acquire their mutual connections and separations and so on (the functions and intentions). They superimpose other kinds of diversity. These higher-order variables (e.g. concentration/de-concentration, openness/seclusion, mono-functionality/multi-functionality) regulate the distribution, connection, separation and use of the same content in different ways. For this initial exploration, I do not pay much attention to the distinction between primary and higher-order variables. It provides some examples of variables that may be distinguished in any environmental diversity.

R=1m, ‘Grip space’

Child

You may have explored environments R=1m most intensively when you were one year old. Within a radius of 1m around you, differences can be observed in temperature, between hard and soft and in the mobility of objects (see *Fig. 19* on page 59). ‘Object mobility’ may vary between *meuble* (mobile) and *immeuble* (immobile). You can imagine a range of object mobility (e.g. a wall, a cupboard, a table, a chair, loose commodities and utensils). This range is largely related to the size of the objects. Although larger objects are less easily moveable, designers have the possibility of making them more mobile by providing them with hinges (as with doors and windows), wheels or similar attributes. Smaller objects can be either pendulous or affixed to larger ones. This kind of environmental diversity is important to the sensory-motor development of a child. Children need stable, reliable elements, as well as dynamic ones, which they can move on their own initiative. For example, imagine the fence of your playpen and your toys. The experience of moving yourself teaches you ‘distance’ and object constancy through parallax. Throwing your toys out of the pen is an exercise in object constancy. It adds a variable ranging from the values ‘within reach’ to ‘beyond reach’ and from ‘safe’ to ‘adventurous’.

Adult

For an adult, stable gradients of movability sustain the ergonomically efficient routines of a household between those objects that are used more and less often. For example, in the kitchen, ingredients or utilities that you seldom use are stored in the back of the kitchen cabinet or at higher or lower steady locations. The objects that are used more often are more accessibly located and mobile at eye-level in front or at hand-level on the counter. In addition to object mobility, many other environmental variables (e.g. fabrics, their texture and colour) may determine environmental diversity and the possibilities for diversification by design. A designer can relate these differences to the variable of mobility, assigning different textures or colours to objects according to their mobility. Which variables relevant can you add?

R=3m, 'Room'

Movement and visibility

You may have become fully aware of R=3m environments when you were three years old. Although you are surrounded by many environments with a radius of approximately R=3m (1 to 10m), let us take the room as an example. The potential presence of daylight may be an important variable for environmental diversification within this radius. This variable may vary according to the distance from the windows, which are structures that connect you with daylight, while separating you from low temperatures, wind and rain. Windows determine the relative sensoric isolation of places in the room. They 'structure' the room from sensory 'open' to 'closed'. They create different functional potentials for each place in this environment. You may locate your desk close to a window, while placing your bed in a remote corner. Nonetheless, the positions of objects are not determined solely according to their potential access to daylight. The interior contains additional diversities that remain at night. For example, the distance from doors to the most remote corners also determines the layout from a motoric kind of 'openness' and 'seclusion'. The distance to the walls may divide the room into a largely unbounded centre and peripheral places that are more determined by the walls as boundaries. Zonings around windows and doors constitute a structure that limits your functional possibilities.

More variables

An even earlier question concerns the description of the diversity of place values and the variables to which they belong. This does not yet refer to the structure and operation of a room, with its second-order variables ranging from 'openness' to 'seclusion' or 'shelter'. The fact that content or form may *cause* (or be caused by) structure is not the first issue in a *conditional* sequence, even if structuring is your first priority in design. The challenge of this study is first to distinguish the first-order variables and values that are capable of differentiating places in a room. This 'content' may be a programme that precedes your design. Which other variables are available to enrich, cover, weaken or even avoid these kinds of structural diversity by adding content? The same content still allows different compositions, structures and functions to be chosen by design or use.

R=10m, 'Building'

House, tree, street

An environment of R=10m is the environment you may have discovered when you were five years old. It is also the radius of a large, 50-year-old tree or a large house. An urban environment of R=10m may contain one large or several smaller building units and adjacent gardens or a street to cross. If many rooms together are connected to public space by one entrance, they make up a 'building unit', in which the connections of the rooms with the entrance differ in length. This length differentiates the rooms into categories ranging from remote, more isolated and private rooms to rooms that are more directly connected and open to the street. One challenge may be to design many intermediate values (reinforced by variables other than accessibility) in what Alexander referred to as an 'intimacy gradient'.[a] This gradient can be best unfurled from front to back in a 'long, thin house' with inner courts to provide the rooms with light and air.

Dwelling breadthways accessible

In more usual dwelling layouts, however, you can often recognise the same difference of accessibility breadthways. In this context, the difference appears over a smaller distance as a sharp contrast between the hall and the living room. Even if it is realised at a smaller distance, it belongs to the nominal 10m range of *possible* measures. It is accompanied by

[a] Alexander (1977) *Pattern Language* (Oxford) OxfordUniversityPress

differences in temperature, moisture, materials, texture, activity and layout. A house with a walk-through lounge on one side may have a hall, a corridor and a kitchen on the other side. On that side, all connections of the house with the external world are concentrated: the front and back door, the staircase, the water, gas and electricity supply, their tubes, the sewage, the mailbox and similar attributes. The walls are often covered by moisture-resistant, easy-to-clean tiles in moderate colours. This environment supports movement and physical activity better than does the living room, with its vulnerable chairs, tables and wall-paper.

Movement and rest

Physical activity does not require much distraction by the pictures, ornaments and baubles that you may like if you are at rest. The concentration of connections on one side of the house protects a more isolated living area from the accompanying dynamics on the other side. The R=10m *motoric* polarity from 'open' to 'closed' between rooms is an extension of the R=3m motoric mentioned above within each room conditioned by the position of the doors, although it has different effects. This polarity is definitely different from the R=3m *sensoric* polarity, to which it often appears in a perpendicular relationship. The R=10m polarity may thus also appear vertically. The decreasing accessibility from ground floor to the attic also conditions the diversification of dynamics and the associated potential diversification of functions between the storeys.

R=30m, 'Building group'

At seven years of age, you may have become familiar with R=30m environments (see *Fig. 20*). An urban environment R=30m may include several buildings, gardens and adjacent public spaces. One of the most striking variables within this radius is once again from open to closed. An environment of R=30m contains external variables different from those applied and applicable in the interior of a building. It shows the contrast between being inside and being outside – the façades on the front and backsides of buildings. It challenges the designer to make such intermediate areas as covered outside spaces and internal open courts. It encompasses the difference between the public residential street and the private backyards and back-paths of buildings. Moreover, it determines the mutual position of buildings and building units, gardens, parking space and public space. The position and orientation of buildings and trees determine variations in the access to sunlight and shadow in the open air, which subsequently cause variations in use and in the character of the vegetation, the location of street and garden furniture. Public illumination, visibility and safety may become important variables. The alternation of planted and paved surfaces, the distinction between pedestrian surfaces with tiles and surfaces accessible to other kinds of traffic with bricks or asphalt usually constitute differences with sharp boundaries. This radius still contains many variables between architecture and urbanism.

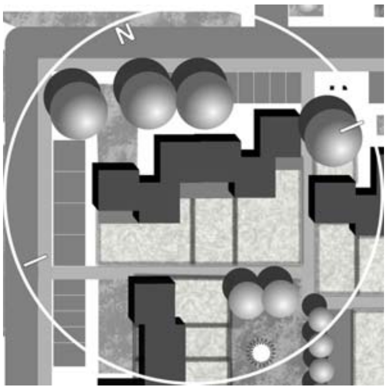

Fig. 20 Building group R=30m

Fig. 21 Ensemble 100m

Fig. 22 Neighbourhood 300m

R=100m, ‘Ensemble’

Crossing the street

At nine years of age, you may have become familiar with environments of R=100m (see *Fig. 21*). These environments encompass the ensemble of some residential streets and some different building groups, possibly of different styles. You may have crossed these streets on your own to meet friends. You probably promised your parents not to cross the larger neighbourhood or even district roads, except if that crossing was necessary to go to school. As border crossings of your territory, such crossings were probably safeguarded by adults or by traffic lights. At that time, the further route to your school was probably allowed without deviations. You know them only by the buildings you passed each school day. Your school had thus become your second territory of R=100m, along with its playgrounds and its adjacent sporting fields.

A one minute walk

For many adults this is also the radius of shopping trolleys, of district centres visited every day, of pedestrian ensembles of shops and larger parking spaces (see *Fig. 23*). Some large buildings may have this radius (see *Fig. 24*). The income of the inhabitants may visibly vary within the ensemble. It is also the radius of the smallest parks, which usually have a small pond, surrounded by more expensive houses and their gardens. Which environmental variables determine the diversity you encounter by walking one or two minutes in an urban environment? One of these variables is the distance of direct view at which you can still identify the separate buildings or shops.

A 100m forest vision

This is the distance at which you can survey a forest; it is the environment of dimmed light gradually bounded by trees and bushes. This is where your eyes evolved to have their present stereoscopic abilities and where they obtained their final resolution. It is also the radius of a palaeolithic village of hunters and gatherers, the communities in which humans lived for millions of years before the invention of agriculture made larger settlements possible. The time that has passed since this development (the Neolithic revolution) accounts for a mere 1% of the entire period of human existence. This range is an archetypical radius in which your familiar scope of control within a one-minute walk ends and where the rest begins, filled with invisible noises, uncertainties and dangers. It is the radius within which you still can call your children.

A 100m span of control

Perhaps the most appropriate variable for R=100m environments would be ‘span of control’ or ‘primary scope’. This variable ranges from ‘open’ to ‘closed’, but with a character that is different from that of the previous radials. Visual accessibility varies from introvert streets to extrovert crossings and from inner private courtyards surrounded by buildings to public space opened up by streets. Within this radius, there is a wider variety of quietness and business than can be observed at a distance of 30m. It is the average view from the seclusion of your room into the outside world; it is the distance at which you can still recognise people or events that can please or frighten you. For the purposes of this study, however, it is important to know which of these variables are relevant for design and which of them can be strengthened or weakened by design means. For example, why did I never see such a supporting sequential diversification of building groups in a gradual transition from a horizontal into a vertical articulation of their architecture?

R=300m, 'Neighbourhood'

A 5 minutes walk

A contemporary urban environment of R=300m (between 100 and 1000m radius, or between 1 and 15 minutes walking) is usually known as a 'neighbourhood' (see *Fig. 24*).
It is an area of nominally 30ha (varying between 3 and 300ha) and 1 000 inhabitants (varying between 100 and 10 000). A walking distance of 300 metres to a primary school or a public transport stop is acceptable. Within this radius, different ensembles and dwelling types can be distinguished and composed. Each ensemble may house a more or less homogeneous category of inhabitants (with regard to income, stage in the life cycle or lifestyle[a]). In the 17th century, all towns in the Netherlands[b] had a radius of approximately 300m, with the exception of Amsterdam and Dordrecht (R=1km). A 300m radius was apparently an optimal size for a complete urban economy and its defence. Many of its urban functions are currently performed at a larger scale in special neighbourhoods, separated from the exclusively residential areas. A town of R=3km with 100 000 inhabitants may still have a town centre of R=300m (see *Fig. 25*).

Fig. 23 R=300m with a District centre r=100m

Fig. 24 R=300m with a Large building r=100m

Fig. 25 R=300m Town centre

Diversity of age

For example, ensembles may contain either a substantial number of children, primarily adults who do not yet have children or a majority of elderly people. Their allocation may thus be selectively attracted to schools, health care centres, small businesses, shops, pubs and other facilities required for some 1 000 inhabitants. Such facilities may differentiate in terms of content, form, structure or neighbourhood function as these categories crystallise.
The stage in the life cycle may select specific categories of inhabitants according to their specific requirements. For example, if 10% of the population consists of children up to 10 years of age, facilities for playgrounds, crèches, nursery schools and primary schools may attract families with children. These facilities serve as meeting places for parents and as potential sources of social cohesion. You may need some 200 pupils for a primary school, eventually located at the boundary of a neighbourhood, thus allowing it to serve two neighbourhoods. Its requirements with regard to safety, greenery and daily pedestian accessibility may be combined with some other functions (neighbourhood park, homes for the elderly, health care), but they are separated from the more dynamic (i.e. less safe) ensembles.

[a] Michelson, W. (1970) *Man and his urban environment: a sociological approach* (Menlo Park, California) Addison-Wesley Publishing Company, Inc. Philippines
[b] Blaeu (1652)*Toonneel der Steden* (Amsterdam)

Diversity of life style

This pattern may result in zoning ordinances around primary schools that differentiate the area. The other pole is thus the connection of the neighbourhood roads with a larger external road collecting the traffic from several neighbourhoods. These connections provide access to clients, employment and careers elsewhere. This pole may be combined with smaller starter dwellings in higher-density areas, along with small businesses (including home businesses), services and possibly some neighbourhood shops.
Which environmental variables (kind of plantation, street furniture, enlightening, types of pavement and roads) may support that potential polarity from quiet and introvert into more dynamic and extravert? Such segregation between the familist and careerist lifestyles, however, may also occur at the larger radiuses of a district, a town or even a conurbation of R=10km, with a busy centre for consumers, a well-disclosed transition zone for careerists and silent R=3km suburbs for familists. In these smaller areas, however, the teenagers of these familists may become bored. At this point, which variables may differentiate the R=300m environments?

Larger radiuses expressed in kilometres

Discontinuous view, rarefied zones

Even in your early youth, you may have seen areas larger than the neighbourhoods you knew from direct exploration by visiting the higher storeys of tall buildings or flying in an aeroplane. These views must be connected to earlier experiences (‘Look! We walked there!’). These connections are not self-evident. The known neighbourhoods are separated by rarefied zones[a]. You need some spatial imagination and reason to understand such views, as with the views provided by Google Earth, its applications or the maps of an atlas. In an atlas, thematic maps show a great diversity of legend units within even larger radiuses. You cannot immediately observe these categories on the ground. They may nonetheless be relevant for many kinds of actions, for the understanding of what you see on the ground and for spatial design.

Maps and legends

For example, an authoritative atlas of the Netherlands[b] contains maps distributing many values in space as legend units. Some of these values are listed in *Fig. 26*. They are relevant within different radiuses. I indicated the radiuses within which I could recognise substantial differences by looking at these maps. But, what is “*substantial”?* The colours chosen in the map may suggest differences based on arbitrarily chosen statistical class boundaries, and within a larger radius I may have recognised groups of similar colours as *substantially different* from other groups. Very detailed maps cover more levels of scale. In most cases, however, differences smaller than R/100 are not observable in the map’s frame R. Its resolution is thus <1% in most cases. Smaller distinctions are reduced to an average value for the smallest unit (grain). The *average values* are named in a legend. This legend may show the ordinal sequence of a variable. These values are sometimes numbers (e.g. altitude), but largely the units are distributed on a different basis (e.g. geology). They may relate different values, or they simply may represent accidental (e.g. historical) singularities. Many of these variables are responsible for environmental diversity in more than one radius. The same name may have a different meaning on another scale. For example, within a radius of 10m, the income of your neighbour may be different from yours. You can draw this conclusion if your neighbour’s house, garden or car appears to be more or less expensive than yours. However, the atlas also shows a map with differences of *average* income between provinces within a radius of 100km. This determines a kind of environmental diversity other than that which you have experienced within your own neighbourhood.

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[a] Groenman (1960) *Het disconitue wereldbeeld* (Mens en maatschappij)35 p 401-411
[b] Bosatlas (2007) Bosatlas van Nederland (Groningen) Wolters-Noordhoff

Variables varying within R=	1m	3	10	30	100	300	1km	3	10	30	100	300	100	300	100	Page
altitude											1					183
altitude				1			1	1								205-221
geology									1	1	1					179
geomorphology										1	1					185
water storage capacity									1	1	1					186
lithology								1	1	1	1					189
soil						1	1									188
soil						1	1	1	1	1	1					189
landscapes									1	1	1					201
agricultural occupation types									1	1	1					222
residential environment								1								226
travel time into a centre									1	1						227
land use 1900							1				1					230
land use 2004							1				1					231
allotment					1	1										234
groundwater										1	1					244
catchment basins												1	1			244
hydrology											1					245
subsidence									1	1	1					246
below sea level										1	1					247
flood probability										1	1					248
water-boards										1	1					251
mediaeval dammings										1						252
ecological districts										1	1					260
nitrate							1		1	1	1					276
noise nuisance			1	1					1	1						278
population increase									1	1						296
live expectancy										1	1					368
cancer casualties										1	1					371
smokers and drinkers										1	1					373
economic power											1					402
added value									1		1					403
income					1				1	1	1					404
employment/1000 inh.15-64yr									1	1						413
employment/km^2										1	1					413
unemployment										1	1					417
commuting									1	1	1					420
vegetative agricultural products								1			1					429
pigs											1					430
chickens											1					431
maize											1					433
employment industry										1	1					438
employment distribution										1						440

Fig. 26 Several themes in maps published in the 'Bosatlas van Nederland' 2007

Statistical differences

This discussion raises several important methodological questions that must be clarified before I continue to explore possible variables for each radius. First, thematic maps usually show statistical differences. The different colours of a legend thus represent statistical classes with selected boundaries (e.g. 0-9%, 10-19%). If these classes had been larger (e.g. 0-19%, 20-39%) or smaller, the map would have shown larger areas in fewer colours or smaller areas in more colours. In this case, my conclusion regarding the level of scale at which the difference is 'substantial' would have been different. However, I trust that the authors are experienced specialists. They probably had a reason for selecting their statistical class boundaries and the number of contrasting colours representing them. They must have chosen them according to their experience, in order to bring these differences to my attention as meaningful.

The scale of the legend

Second, some variables may have a meaning at any level of scale, as is the case with differences in altitude (e.g. from table to mountain), although they appear in the atlas only for the radiuses of 3km and 100km. The map showing altitudes at R=100km neglects the altitude differences between houses and streets in order to show the average differences between the East and the West of the region. These choices determine a different environmental diversity. There are many other radiuses, however, within which altitude may differentiate the environment in ways that are useful for *design*. For example, a slope or an inclined street may differentiate the higher urban environments from the lower ones at R=100m, R=30m or even R=10m. I will not refer to altitude as a design tool at every radius. I choose one radius at which it may be most 'substantial' for environmental diversification by design. Readers or designers are free to experiment with their capacity to diversify environments within radiuses other than those mentioned here and in the next chapters. This exercise corresponds with the aim of this enterprise to extend your design tools.

Neglecting what is not measurable

Other questions concern the choice of the actual themes. Do they also cover the *possible* environmental diversity? Do they overlap? Are they probably related as cause and effect, or do they conceal a common variable that is not shown? Conversely, you could question whether a commonly accepted cause and effect (e.g. the relationship between smoking and cancer) may be falsified by a lack of spatial relationship. For example, the map of cancer casualties shows a pattern that is very different from the map of smokers. There may be other variables than smoking (e.g. 'stress') that could explain the number of casualties from cancer. Human stress is difficult to measure, however, and there may be no statistics about it in relation to the surface represented by the map.

Other variables than measurable, true or probable

An atlas is intended to represent the *truth* or at least a *probability* to the extent that it is measurable. This is not the only problem I wish to address. I would also like to address *possibility*, and this cannot be completely covered by empirical research. Design study covers *improbable* possibilities as well (and even in particular), thus *changing* the existing reality. To become fully aware of the problem that this thesis aims to address, it is still important to identify explicitly which differences we can observe, remember or even imagine ourselves within different radiuses. Even then, there may still be categories and variables that do not exist in the usual categorisations of professional empirical geographers.

Exploring possible differences

In the following section, I continue to explore the kinds of diversity within different larger radiuses that we may know from our own direct experience in a more or less 'phenomenological' way. It does not pretend (or even intend) to be complete. It remains a sketch of the problem field. In the next chapters, we may be able to make these problems operational for design, research and policy.

R=1km, 'District'

A 20 minutes walk

A district is an urban area of nominally $\pi R^2 \approx 3km^2$ and 10 000 inhabitants, most of whom usually seek quick access to daily commodities. Walking 20 minutes with children or heavy shopping bags becomes less attractive than driving. Driving 5 minutes in your car as a means of covering a distance of 1km, even if driving would involve some delays due to traffic lights and parking. Broad and busy district roads may cross the district every 1 km through or around a usual district centre for daily commodities. At R=1km, traffic becomes an important issue that structures the district. A district may even have a railway station in its centre (see *Fig. 23* and *Fig. 27*). The railway then would divide the district into two parts.

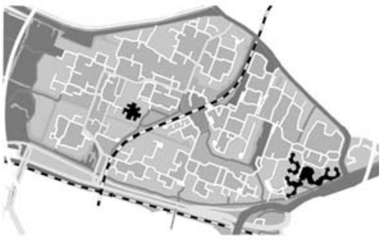

Fig. 27 R=1km Zoetermeer Buytenwegh

Fig. 28 R=1km Zoetermeer Centre and Old Village

Fig. 29 R=1km Amsterdam Centre

Centre and outskirts

From the district's centre into its outskirts, the kind of dwellings may vary from high-density flats to detached houses with low density and more greenery (see *Fig. 29*). However, the location of a district park of R=300m may disturb this sequence and polarity through its own radiating influence, if it is not located at one of the borders. Other boundaries are often urban highways of 60m in width every 3km (mesh width M) . To navigate through your district, recognisable points, lines and areas[a] (e.g. striking objects, nodes, routes, edges and neighbourhoods with their own style) have become important. Which variables may differentiate these neighbourhoods in ways other than by their location and density? Why would you choose to live in one or the other?

Lifestyle differences

At a radius of R=1km, lifestyle may be more important than stage in the life cycle is as a differentiating factor for choosing your neighbourhood. Lifestyle, however, can also play a role in your choice at a larger scale. If you are a consumer, attracted by centres of shopping, services and leisure, you may be more attracted by the centre of a town or even the centre of a conurbation than you are to the centre of a district. In these areas, however, you are likely to have to pay a higher price. The scale that you choose may thus depend upon your age and income. If you are a careerist, you may choose a drive-in dwelling close to the exit of an urban, a regional or even a national highway. If you are a typical familist with young children, you may choose for smaller towns and suburban districts.[b] Within a district, however, lifestyles may already be a source of mutual diversification amongst neighbourhoods. Which variables would you choose in order to distinguish neighourhoods within a district? The possible local differences in lifestyle may be a starting point, but there should be additional factors for differentiating the character of a district in its own right.

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[a] Lynch (1988) *The Image Of The City* (Cambridge Mass) MIT Press

[b] Michelson, W. (1970) *Man and his urban environment: a sociological approach* (Menlo Park, California) Addison-Wesley Publishing Company, Inc. Philippines

R=3km, 'Town'

Amenities
A town is an urban area of nominally 30km^2 and 100 000 inhabitants. Many of a town's inhabitants find their employment and leisure activities within a radius of 3km, while others commute. If they move, they usually move within this radius in order to acquire a larger dwelling. They visit the town centre (R=300m, see *Fig. 25*) approximately once a week. The number of inhabitants is large enough to support a hospital, a railway station, specialised recreational and cultural facilities (e.g. a library, galleries or theatres). They may attract each other by fulfilling the same leisure demands or supporting additional facilities (e.g. pubs and restaurants). Dynamic functions (e.g. railway stations) may attract other functions, including specific types of shops, fast-food restaurants or travel services. This generates polarities between functions that differ from the previously discussed polarities.


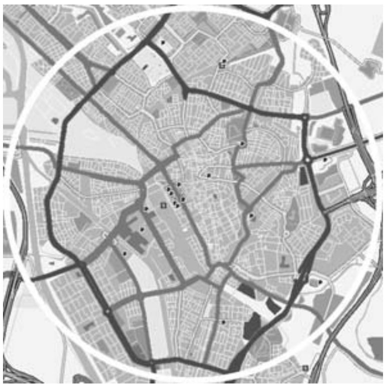


Fig. 30 Zoetermeer R=3km[a] *Fig. 31 Utrecht* *Fig. 32 Leiden*

Crossing your town
Crossing your town in any direction by car in 15 minutes at a speed of 30km/hr, you will pass many differences, although the differences inside the districts may dominate those existing between them. The difference between the older districts in and near the busy centre and the more recently built districts in the quiet outskirts could be more striking than those that can be observed amongst neighbourhoods within a district. It is not only a difference of dynamics, building style or the age of the trees; it is also a different layout. Some older districts may have curved roads, while other districts lead you along long, straight lines with interesting or boring views.

Eccentric growth
That spatially readable history of a town may be manipulated by a kind of planned growth, as argued by Doxiadis.[b] Concentric growth of a town raises pressure on its centre. It expand into adjacent housing neighbourhoods in a sub-optimal, opportunistic way. Eccentric growth creates an opportunity to build a larger new centre next to the old one, removing the same amount of housing areas by public agreement in a master plan. Special cultural or other functions could remain within the oldest centre, as they are not overly sensitive to centrality.

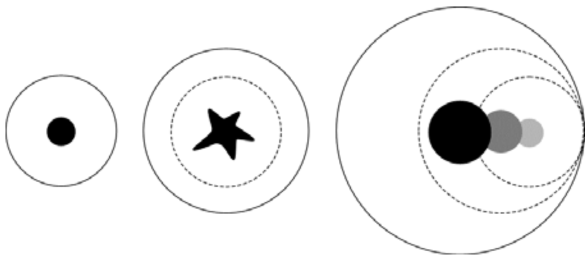

Fig. 33 Concentric and eccentric growth.

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[a] CityDisc, Den Haag
[b] Doxiadis, C.A. (1968) Ekistics. An introduction to the Science of Human Settlements (London) Hutchinson

This strategy can preserve or even restore the identity of the old centre. In the new centre, new economic functions can be realised in a highly efficient and contemporary way. In a third phase of urban extension, the dynamics of economic expansion may require yet a larger centre, leaving the previous centre for administrative and other less dynamic functions between the quiet old city and the new economic core. Through this process, the town acquires new linear urban diversification from historic to contemporary and from cultural and administrative to economic. This was the case in Utrecht. From 1960 onwards, a shopping centre was created that extending over the railway station. This preserved the identity of the old centre while serving the western extensions on the other side of the railway. Perhaps you can find additional R=3km variables that could differentiate an urban body in the other directions.

R=10km, ‘Conurbation’

A million inhabitants

A conurbation is an urban area of nominally 300km^2 and 1 000 000 inhabitants, often composed of several townships, former towns and villages. The former settlements, each with its own history and identity, may now be captured within a radial web of the central city.These settlements have lost functions in favour of the central core. Their skyline has become less recognisable since their rural surroundings have been urbanised, thus filling in the meshes of the web.

The city

The central core, the ‘city’ of the conurbation may also have lost much of its original identity. Its floor space may have increased substantially. This would have necessitated the construction of high-rise buildings and the implementation of radical traffic interventions. The decreased accessibility of the inner city, with its restrictions on transport and parking, may have made it necessary to build a separate underground public transport network for commuting and shopping, in order to connect the suburbs with the emerging exclusively pedestrian areas.
The primary meaning of ‘environmental diversification’ as it appeared in the national plan of 1966 (as shown in *Fig. 15* on page 46) was not a national diversification, but a diversification of residential areas with different densities within a radius of 10km.

Urban highways

The nominal mesh width of urban highways (M=3km) may have been extended by even wider conurbation highways (M=10km) allowing higher speeds surrounding the city and separating it from its suburbs. These ring-ways may have attracted enterprises that require more space and private motorised accessibility than the inner city can offer. At the exits of the ring-way, specialised sub-centres may have emerged for more space-consuming facilities (e.g. hospitals, furniture businesses or financial headquarters). These sub-centres may have radiated their influence into the adjacent suburbs and reserved space in the inner city for new specialised functions. This new spatial division of tasks or ‘specialisation’ within the context of a conurbation may require a new ‘spatialisation’ in order to make their differences recognisable.

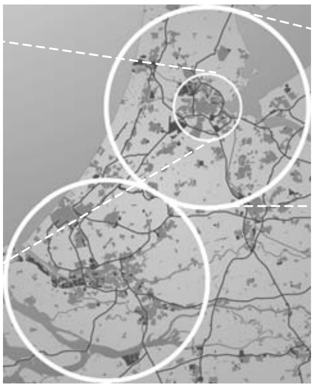
Losing locational value to the internet

In contemporary times, however, jobs and shops are increasingly losing their locational value to the internet. The provision of employment is becoming further centralised into regional highway exits, leaving empty places in the former centres. What is to become of their identity if it should be something else than crime? Shops may disappear in a process reinforced by economic crises. Retail is decentralising further into the home computers of residential neighbourhoods. How can residential areas be diversified if jobs and shops are no longer available to accomplish this task?

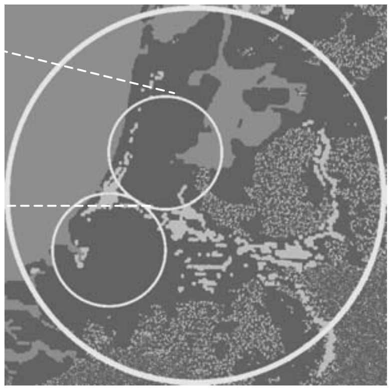
Physical topography

A conurbation may diversify through its physical topography – through differences in its soil, waters and possibly its hills and valleys.

R=10km 2000AD
Fig. 34 Conurbation



R=30km 2000AD[a]
Fig. 35 Urban regions



R=100km 1000AD
Fig. 36 Region occupation [b]

There may be dry, sandy districts and lower and wetter parts on peat or clay, with ponds and waterways. There may be open waterfronts and dry, inner city districts and parts with or without views over the surrounding landscapes. Its centre may be recognisable by high rise buildings. A conurbation may thus contain large open areas with natural, agricultural or recreational functions. They may be scattered over the conurbation. In this case, however, they may not diversify the centre at a scale of R=10km, but at a scale of R=3km or even R=1km. If they form a band surrounding the inner city (thus separating it from its suburban outskirts), or if they form wedges between the urban extensions reaching from the surrounding landscape to the urban core, these functions structure the centre at R=30km. The large and quiet green areas may contrast or alternate with the M=10km highways, which are possibly hidden behind their noise barriers.

[a] CityDisc Den Haag
[b] After Scheele(1990) (Utrecht)UvU

R=30km, 'Urban region'

Amstel dam and Rotte dam

An urban region is an urbanised area of nominally 3 000km^2.
If it is inhabited by 10 000 000 people within its radius of 30km (as is the case with London and Paris), it can be called a metropolis. The urban regions of Amsterdam and Rotterdam (see *Fig. 35*) both show a remarkable symmetry. The Old Rhine flows where they touch each other. This river has been separated by dikes from the reclaimed peat marshes on both sides, descending by drainage. These lowlands were drained by the smaller Amstel and Rotte rivers. The Amstel (which flowed to the north) and the Rotte (which flowed to the South) were dammed (thus Amstel-dam and Rotte-dam), in order to prevent seawater from flowing inwards. In 1000 AD, the Old Rhine was an axis of early occupation between the old towns of Utrecht in the middle of the Netherlands and Leiden in the west (see *Fig. 36*). Utrecht suffered from floods and dammed its useless shallow Rhine branch in 1122 AD. At this point, its water and ships largely followed the southern course along the present harbour of Rotterdam.

Physical history

This example demonstrates the role of physical history in the understanding of an urban region. Rivers play a dominant role in the origin of settlements. Conurbations grow some 30km from the sea or large waters in order to acquire sufficient hinterland within the 30km commuter distance of their urban region. This hinterland may differentiate into different quarters. The Amsterdam urban region has more expensive residential towns and villages within the sandy areas of its south-eastern and western dune quarters. It has a large lake on its north-eastern side, smaller lakes in the south, and open land to the north. The Rotterdam urban region shows less diversity. Its historical core was bombed in the Second World War. Its vast harbours extend into the west. Within its 30km view bounded by the horizon from a 25th floor, it has a vast greenhouse area to the northwest and The Hague, which is the seat of the national government, as a fashionable second conurbation. The other quarters are primarily rural lands with small natural reserves and forests. At its south-eastern boundary, however, lies one of the oldest towns of Holland, Dordrecht (which once housed the Parliament of Holland). On the other side of the river, Dordrecht faces an adventurous landscape of waterways and bushes that are reminiscent of the country's oldest scenery.

A Sunday cycling tour

Which variables could you apply for further environmental diversification at a level of R=30km? Its components are landscapes and townscapes diversified by ecology and history. Its design tools are landscape ecology, regional history and archaeology. At this level of scale, climate change may have a substantial impact on current policy. In the Netherlands, the incidentally expected sudden overloads of water flowing down from Switzerland, Germany, Belgium and France require more room for the rivers. Between their dikes, they are too narrow for that capacity. That policy may result in occasionally flooded river landscapes crossing urban regions. New natural reserves may diversify their environment, thus bringing their inhabitants closer to an awareness of nature and the oldest scenery of the country, in contrast to the fabricated environment of towns. The awareness of history may be encouraged by archaeological reserves that remain hidden in the soil. Looking down into its excavations or looking up to its historical buildings may bring you back to another culture, tacitly confronting you with the current dynamics of your time. You should have access to many of such places of reflection within a radius of 30km. This is the radius of a Sunday cycling tour or the distance of a mediaeval day hike.

R=100km, 'Region'

Cultural diversity

An area with a nominal radius of 100km is often called a region.

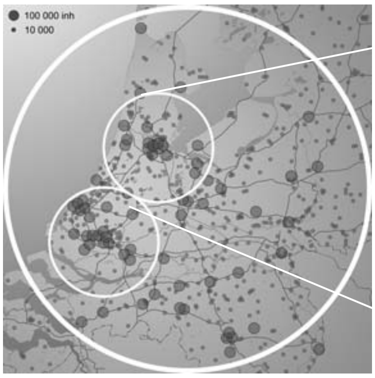


Fig. 37 Region R=100km
with characteristic sub-regions R=30km

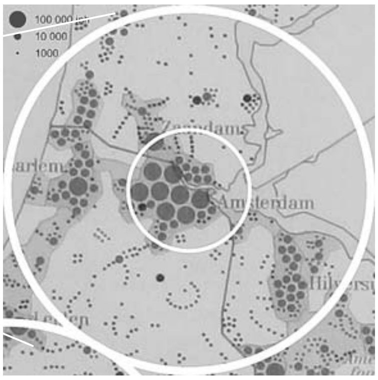


Fig. 38 Conurbation R=30km Amsterdam 1979[a]

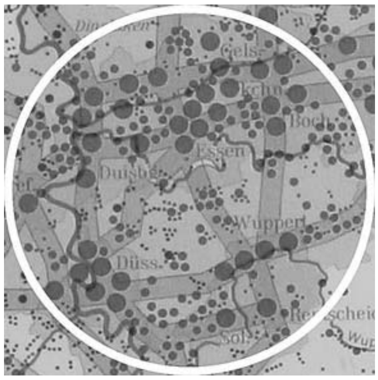


Fig. 39 Conurbation R=30km Ruhrgebiet 1979[a]

Areas of this radius seldom cover a nation, but a small country such as the Netherlands, nearly does. Within this radius, there can be unusual diversity. Even the language may differ to such an extent that people living 200km apart cannot understand each other speaking in their native dialects. This is the case between the North and the South of the Netherlands, which have been historically divided by the rivers Rhine and Meuse. These rivers formed the boundary of the Roman Empire and were an important border during the 80 years of war between the Catholic Spanish heir and the Protestant Dutch Republic fighting for its freedom four centuries ago. The country still shows evidence of these differences in culture on both sides of the rivers.

Soil

Perpendicular to this cultural variable, nature has left behind an even more substantial difference at this level of scale. The higher sandy soils in the east gradually turn into the lower and wetter clay and peat polders of the west. The landscape changes dramatically as you cross the country in that direction. A century ago, the sandy soils were less fertile. Prosperous agriculture in the east was limited to brook valleys. The underestimated invention of artificial manure to be produced at an industrial scale by Justus von Liebig in the 19^{th} century changed the world, however, and it changed the agriculture in the east of the Netherlands as well. Poor soils could now be used for agriculture. This reduced the area of nature in the east and consequently the natural diversity of the region. Is technology always doomed to homogenise our environment, or does it also provide means to diversify it?

Urban and rural

The development of rapid modes of traffic made very large concentrations of people possible. The rural areas consequently became emptier (see *Fig. 38* and *Fig. 39*). This process has diversified the picture within the radius of R=100km. Within a radius of R=30km, it has caused an opposite effect, making the homogeneous sprawl of sub-urbanisation possible. This provides a nice example of the scale paradox (see *Fig. 7* on page 21). Technology has opposite effects of up-scaling and downscaling processes of production and distribution. It raises the question regarding the level of scale at which particular types of diversity are to be desired.

[a] After Griep(1979)*Atlas Encyclopedie*(Utrecht)Oosthoek

Physical and social differences
Taking the urban regions of Amsterdam and Rotterdam as a starting point (see *Fig. 37*), you may recognise the historic division in provinces as surrounding sub-regions of equal size. Although they show a clearly different identity, it is difficult to identify the variables responsible for this diversity. If you study the maps of a national atlas, you will find numerous spatial, ecological, technical, economic, cultural and governmental values as legends (see *Fig. 26*). Many of these values, however, determine the diversity within radiuses much smaller than the R=100km scale of the map. How should you identify combinations of these as values of 100km variables in order to acquire a grasp on the potential diversification of a region?

Economic specialisation
Fifty years ago, some of these overall differences were more recognisable than they are now. Amsterdam was the centre of culture, Rotterdam was the centre of trade, The Hague was the centre of government, Utrecht was the centre of conference and other cities were the centres of industry, different branches of agriculture or specific services. These clearly distinguishable characteristics disappeared. The advancement of technology made any place suitable for any purpose. Any sub-region now has its own facilities for culture, trade, conference, industry, agriculture and services. If you would like to find more contemporary characteristics, you should perhaps consult leisure and travel folders rather than an atlas. They try to convince you to visit particular regions because of their unique character.

R=300km, 'Land'

Lands
In Europe and the US, the 300km radius is largely the radius of states or lands.
The term 'land', may have a less governmental connotation than 'state".

(light) <90..100(EU)..110..120.. (2011) (201201) <4..6..8..10..12%..(dark)

Fig. 40 Europe Altitude[a]

Fig. 41 GDP/inhabitant and Unemployment R={1000,300km}[b]

The environmental diversity of lands R=300km is largely determined by physical differences. The physical differences are the result of long-term geological processes locating the sea and the land, culminating in its higher mountains (see *Fig. 40*).These differences determined the catchment area and the course of major rivers (e.g. the Rhine see *Fig. 42*). The river Rhine has attracted people and their economic activities, thereby resulting in a densely populated axis in Europe with relatively small dispersed cities (see *Fig. 43*). A ring of large solitary metropolises surrounds that area clockwise: Hamburg, Berlin, Vienna, Milan, Lyon, London and Birmingham.

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[a] European Environment Agency (EEA) http://www.eea.europa.eu/data-and-maps/data/digital-elevation-model-of-europe
[b] Eurostat(2012) http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

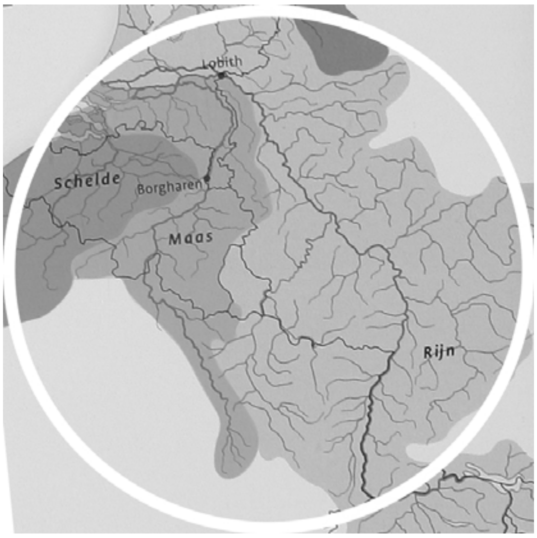

Fig. 42 Catchment areas R=300km[a]

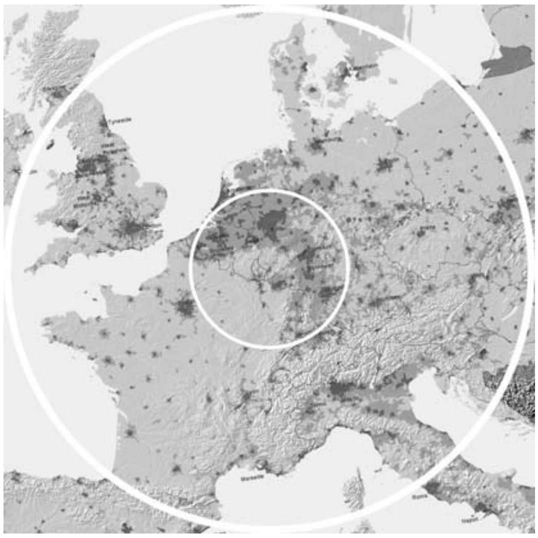

Fig. 43 Urban density R={1000km,300km}[b]

A historical coal mining area crosses the Rhine supporting its industrial core (Ruhrgebiet). The economic diversity of primary (agriculture, mining), secondary (industry) and tertiary (services and trade) sectors has historically been conditioned by this physical zoning. Many economic variables (e.g. Gross Domestic Product, unemployment see *Fig. 41*) follow such diversity, but they change according to a global shift of sectors.

The level of scale conditions the content of diversity

From a phenomenological …

These examples are not intended to be complete. They are a first step exploring the problem of environmental diversification without any other assumption than the concept of scale. They merely demonstrate that such a concept may acquire at least 12 very different contents. The composition of variables responsible for environmental diversity changes throughout the scales. A fundamental study of environmental diversification from the perspective of possibility should start by ordering these variables systematically according to the scale of their working. If they work out differently at different levels of scale, they should be distinguished further to encompass their environmental working. For example, if 'altitude' diversifies R=1m environments in manner other than it does within R=300km environments, the variable 'altitude_{1m}' will be different from 'altitude_{300km}'. Their frames and grains differ.

…into an operational content

Chapter 3 will try to make variables operational for design practice. Even then, however, it remains a trial run. Its selection continues to contain the subjective element of a choice from amongst a multitude of imaginable variables. This study may encourage to add your own variables, in order to enrich the supply of design tools in any radius. Despite the unavoidable incompleteness in studying the content of environmental diversity, it still allows the study of diversity in the ways in which their values can be dispersed within an environment (morphological diversity), combined (structural diversity), used (functional diversity) and intended (intentional diversity). The analysis of these meanings of diversity are thus not completely dependent upon a correct determination of the available variables. These meanings will have their own limitations, however, thus limiting the questions and problems to be addressed in this study.

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[a] Bosatlas(2007)
[b] Eurostat(2012)

2.6 Limits of 'diversification'

More than content

Content is the basis of environmental diversification. This study is limited to contents that can be expressed in variables, categories that can be divided in subcategories with a rational (not necessarily quantitative) sequence – in other words, 'values' or 'legend units'. This study subsequently assumes that any single well-defined variable of this content still has many different possibilities for dispersing its values in space (i.e. forms). If this distribution has extremes (e.g. accumulation and sprawl), the distribution itself may be expressed as a variable of second order. The morphological diversity covered by this study is thus limited to the diversity that can be expressed as values of this second-order variable. There may also be a third-order variable for structures that stabilise forms, a fourth-order variable for functions using structures and a fifth-order variable for intentions steering functions. Although the search for variables imposes substantial limitations on the enterprise, the possibilities remaining within these restrictions are infinite.[a] This section is an attempt to achieve further limitations.

Artificial and natural diversity

In the previous section, I acknowledged and identified several environmental variables at 12 levels of scale. In the rest of this study, these variables must be elaborated and extended. Nevertheless, they will never cover the full diversity of environments ever observed, imagined or even possible. The advancement of technology will enable new possibilities that will surprise us as they have before. However, these advancements may increase the environmental diversity only at some levels of scale, while decreasing it within other radiuses. This has happened before as well. For example, our homes currently house fewer people and have more rooms on average than ever before, and they are filled with more furniture, clothes, utensils, pictures and books than ever before. This variety in the home may serve to compensate for the sensory deprivation we may experience elsewhere. Young children today are still discovering a world full of things that they have never seen before, but teenagers have seen it all earlier. They become bored by repetition in space and time. They want to meet other people, they look for adventure, they want to travel. If they do, they discover the same kinds of buildings, hotels, shops, rooms or utensils everywhere. They have unlearned the urge to kneel down and take a closer look at the peculiar plants and insects they may pass. They can impress their friends more by wearing the latest fashions. Compared to the inconceivable diversity that we inherited from nature within any radius, our artefacts look poor. Once they cease to be handiwork, they are produced in large series without variation from one item to the next.

Lost diversity

The human population is increasing in numbers as never before; it has conquered large areas of nature and covered it with buildings, pavement and parks with cloned plantations. The house you once bought for its magnificent view lost that advantage as new buildings have spoiled it, decreasing its exceptional value. Environmental diversity has become concentrated in the interior of your home. Even in this environment, however, the variety of change may be lacking. This bothers your teenagers. The majority of the neighbourhoods, districts, towns and conurbations on Earth are environments that are boring to the human senses and experience. People stop looking at the television or the newspapers because they contain no 'news'. Journalists desperately looking for news may find ever fewer peculiar facts to report. You have read it all before. Our production reaches the limits of globalisation to produce the largest series possible. The television and the newspapers become filled with advertisements for new things that are not actually new anymore.

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[a] The Dutch poet J.A. Deelder expressed it as follows: 'Within the limitations, there are as many possibilities as outside'.

Urban diversity

When was the last time that you went out for a walk in order to enjoy your neighbourhood (as your younger children still do), your district or your town, or for any purpose other than to visit its shops? What did the urban designer do to make it an adventure, gradually alternating the view and changing as the weather and the seasons? The only changes that may invite you for a walk are your neighbour’s new car, a demolished building or an accident. An urban designer cannot do much if people do not wish to pay for anything other than private property. In this preference, they are being pennywise and pound-foolish. They have forgotten the impact that other aspects may have on the value of their houses should they decide to sell them or when they calculate the value of the mortgage. Urban designers also cannot do much either if they have unlearned the habit of using design instruments and variables for environmental diversification within radiuses larger than R={1, 3, 10, 30m}. What can be varied at these larger scales? It is difficult to find relevant variables, and I do not want to limit their number. This number has already been limited too much by a lack of imagination. On the contrary, the reader is invited to add more variables, given that a lack of content is accompanied by a lack of form, structure, function and choice.

Distribution, a second order variable of form

If the content has been sufficiently explored in terms of variables, the possible distributions of their values in space (‘form’) can be studied. Even if that study is restricted to the possible distributions of one legend unit at one level of scale, however, it cannot cover the full range of all possible forms. It cannot cover all black-and-white pictures that will ever be made, let alone all works of pictorial art that are *possible* using a single colour. What should we think with regard to additional colours (legend units) and levels of scale? Such is the case with spatial design. To neglect this kind of differences is to make the study irrelevant for spatial design. In this light, what limitations would be useful for studying morphological diversification?

Distribution between accumulation and dispersion

Within a radius of 10km, it appeared useful to study the theoretical extremes in the distribution of floor space, built-up, paved or green space. At a given level of scale with a determined frame and grain, the zero point is total *dispersion*. ‘Distribution’ is thus a second-order variable ranging from total (regular) dispersion or sprawl to total accumulation. For example, it bounds the differently coloured values of *Fig. 15* between these extremes. The extremes themselves can be drawn as a complete dispersion of a given black surface (in its smallest units) over a white field, resulting in either a dotted grey or a single black dot with the same black surface (accumulation).

Diversification by partial concentrations

Any change within this homogeneous grey field of regularly or irregularly dispersed dots is a kind of concentration, a partial accumulation that may produce a pattern of agglutinations, be they lines or surfaces (e.g. the road system, the floor space, the built-up area, the green area). Such diversification of possible dispersions within a radius of 10km formed the foundation for thinking about environmental diversification. In this study, it provides a starting point for the study of morphological diversification at any level of scale. The limited interpretation of ‘form’ as ‘state of distribution’ limits the morphological study in a way that is relevant for design. It leads to the question of whether it can be applied to other variables and other levels of scale.

A combinatoric explosion of possibilities

This approach, however, still does not answer the question of how to cope with drawings containing more than one colour (i.e. more than one legend unit) dispersed within the same drawing. The distribution of one colour conditions the possibilities remaining for the dispersion of a second colour. Changing one distribution changes the possibilities for the second. Designing changes both. Designing rearranges legend units that represent categories of use and construction, with the ultimate goal of achieving optimal mutual contact or distance. Designing arranges connections and separation. It creates *structure*. This involves more (or less) than checking all combinatoric possibilities of dispersion. There should be a shortcut for avoiding this type of endless exercise.

Relations between variables and values

The preceding discussion leads to the question of how adjacent legend units are related to each other as values of different variables and how they attract or repel each other according to different criteria. If there are c categories or legend units, c(c-1) relations will be possible. In empirical research, variables are usually related to each other supposing a determined sequence of their values. A value x_1 is thus related to y_1 in the same way that x_2 is related to y_2 and so on, generalised as y=f(x), although this is seldom the case in a drawing. Legend unit x_1 can be drawn adjacent to y_2. This may produce a spatial relation that differs from the general relation y=f(x). It increases the number of possible relationships between every pair of values y_n,x_n, up to n_{max}^2.In empirical research, relationships are usually well defined; if possible, they are even defined in a quantitative sense. What if they cannot be quantified? What if the categories x and y are gradually changing into each other through a vague boundary, thereby producing varying xy mixtures at a lower level of scale, effectively producing a new variable category z between them?

One-sided and many-sided relations

In a drawing, the relationships are never one-sided. A mathematical function y=f(x) is one-sided. A change in an independent variable x causes a change of a dependent variable y. This function may be rewritten as x=f(y) in order to find a reverse relationship, if it has any meaning at all. For example, if visibility (y) is a function of distance (x) according to y=1/x, the reverse function x=1/y would mean that distance would be reduced by increasing visibility. This is nonsense, however, or poetry at best. It switches cause and effect. Increasing visibility cannot be the cause of reducing distance unless its possibility motivates you to move. If this is the case, however, the reverse relationship will introduce other variables (e.g. motion and time). The reverse relationship must be formulated separately as a different function.

Double-sided asymmetric relations

In a drawing, the adjacent values condition each other in both directions, often with unpredictable effects due to numerous context factors. The variables may also change by the hour, day or season. The effect of x on y may thus cause y to have a different on x, just as two neighbours can have an increasing conflict due to successive teasing or because a tree is blocking light to a building (or conversely, because a building is blocking light to a tree).

Hampered relations

Moreover, the values in a drawing may be separated or connected by additional intermediate values, such as walls and windows or dikes and roads (structure). What should we do if these intermediate elements acquire a substantial size as a new legend unit at a higher resolution than a sketch may show?

From values into their boundaries

It may be useful to shift the attention away from the values towards their spatial boundaries. The degree of separation or connection at the boundaries between values is a third type of variable that regulates form (and subsequently content). The content of a room with open windows or doors is different from the content of a room in which the windows or doors are closed. As in the case of form, there are clear extremes of separation and connection in all directions. These extremes may be called ‘closed’ and ‘open’, with different degrees of ‘openness’ and ‘*seclusion*’ in between. These third-order values can be indicated clearly in a drawing.

Seclusion, a third order variable of structure
This leads to the question of whether this reasoning can be applied to any structure, scale, form and content. After all, the drawings of designers consist primarily of lines. These boundaries or links separate or connect spaces that have different functions. These functions are conditioned by specific kinds of seclusion or openness of the area, and they are readable in the drawing as the position of lines. Clients specify only some of the functions. They ask the designer to draw a structure that may house these functions. Experienced designers know that clients tend to overlook functions that are difficult to name and those that may determine the value for subsequent users or owners, should the realised project ever be sold. Experienced architects deliver more possibilities, which pay for themselves if the building must be sold. Moreover, there are always many possible structures for housing the same function. For this reason, the set of possible structures in *Fig. 4* is larger than the set of possible functions. There are also many more design decisions to make than are required to house the intended function.

Multi-functionality, a fourth order variable of function
The primary limitation of functions considered in this study is the restriction to functions for humans and society. I do not study the function of the sun for the moon, or the reverse. This is hardly a restriction, however, if people are aware of the function of nature for humans. Any function for plants and animals may thus have a function for humans and society as well, be it positive or negative.

Positive and negative functions
This leads to another question. A positive or negative function of nature for the human population is different from the positive or negative function of the human population for nature. If you consider people as part of nature, this distinction discriminates between a function of the whole for the parts ('inward function') and a function of the parts for the whole ('outward function').[a] This distinction is elaborated further in Chapter 6.

Inward and outward functions
If any component of a structure has a special function within this structure, then 'structure' comprises a set of functions. As shown in *Fig. 4*, the functions intended in this study are thus primarily restricted to outward functions, functions *of* someone or something *for* a larger structure. In that case, this study would exclude the apparently inward function of nature for the human population. It was precisely this function, however, that we included in the previous paragraph (i.e. if people are aware of the function of nature for humans, then nature has a function for humans).

This paradox can be resolved in part by distinguishing different levels of scale. The scale (i.e. its frame or radius and its grain or resolution) determines that which we call a structure. A park may have a function for a town, which subsequently functions within a landscape. These are different functions. The town is the primary structure determining the function of the park, but the landscape is a structure that conditions the function of the town. If 'park' and 'landscape' are considered as being more 'natural' than 'town', the question can be reduced to the issue of what is meant by 'nature' or by 'humans and society'. Even these terms are scale sensitive. If you speak about 'nature', 'humans' or 'society' in an abstract or a very general sense, without mentioning the intended radius, it may have no use for design. By definition, spatial design also has a level of scale. Many concepts are tacitly scale sensitive in this way. The 'function of nature for humans and society' can thus be outward, as with the function of a park for a town.

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[a] Berting, J.(1976) *Ruiltheorie* (Intermediair)0528

Reasoning from parts into the whole and the reverse
Even in physics, however, it has proven impracticable to calculate complex chemical processes outward from the observed behaviour of the smallest elementary particles. For this reason, chemistry continues to exist as a discipline, taking the behaviour of particles within atoms as a black box, with a relatively predictable average behaviour of atoms. A biological example is provided in *Fig. 126* on page 184, in which a primarily outward approach starting with the behaviour of singular cells is followed by an inward approach to the organism that these cells ultimately produce, in order to remain practicable for understanding. In the same way, it appears practicable to change the primarily outward approach at some point into an inward approach as humans enter the scene. Even if the bottom-up approach is theoretically possible (and even preferable for exploring *possibilities*), it is not practicable. The question is, on which point you will shift from outward to inward description in order to achieve an optimal understanding that is useful for design.

Functioning in a structure
As shown in *Fig. 4*, a function assumes a structure within which it has the function, even if that structure is not explicitly named. Without clarity about this structure, however, it cannot be clear what the function actually is. In theory, this is the ‘inward turn’. If ‘structure’ is scale sensitive, ‘function’ must also be scale sensitive. A shop may have a function for the town and for the region. The function that it may have for you at the scale of your household is only a small part of such a function. If you were the only client, the shop would not survive. The function of the shop plays out within the larger retail structure of the town or the region. At other levels of scale, it may also be a meeting place, a source of income for its owner, or it may be an asset or nuisance to the shopping centre in which it participates. Any object of design may have many functions, be it a building, a neighbourhood or a town. Only some of these functions are listed in the program of requirements a designer may receive upon starting an assignment. How is a designer to cope with the multitude of more and less explicit functions of (and between) spatial objects in order to determine the functional diversity of an environment and its value?

From functions into their differences
It may be useful to shift the attention away from the functions themselves and towards their differences. Any spatial object or any spatial set of objects may have many functions at different levels of scale. The *number* of the object’s functions thus produces a fourth-order variable known as ‘*multi-functionality*’. Objects in space can be more or less multi-functional. A road is less multi-functional than a dwelling. The zero point is ‘mono-functional’ or even ‘useless’. At this level of abstraction, you can still draw interesting conclusions. For example, you may conclude that mutifunctional facilities save space but cost time, while mono-functional facilities save time but cost space.

Functionless space
Places without any actual use may attract the interest of project developers. The place then acquires a function, as a project developer intends to earn money by creating new spatial functions. This demonstrates a special kind of function: intentions. Many functions, amenities, affordances have no demonstrable intention (e.g. the Earth upon which we stand, its gravity, the air we breathe). In addition, you may also desire functions that do not exist, but that are nevertheless possible. These functions motivate action to search for them or to create them.

A fifth order variable of intention
There are more intentions than there are people. People without intention either do not exist or will soon die (e.g. if they do not at least have the intention to eat). On the other hand, people with too many intentions may face a majority of failures and lose their initiative. Most people, however, have several realistic intentions, aims to achieve and motives for actions to realise the functions they want. Individual and common intentions change the human

environment, giving it function, structure, form and content.
You cannot observe the intentions of others, but you can ask about them. If you do not trust their answers, you can observe their *sequence of actions*, which apparently lead towards some result.

Interfunctional actions

I refer to these intermediate actions between initiative and result as '*interfunctional*'. It is typically human to accept many interfunctional actions before the apparently wanted result can be achieved.[a] Animals may show this capacity in a very limited way, often in the form of innate and sometimes learned routines. Learning, earning and saving money, organising, making plans and executing them step-by-step are examples of interfunctional actions that show intentions.

Design as an interfunctional action

A spatial design is such an intention. Its successive interfunctional actions propose the structure, form and content of an environment (often in the reverse order) before it is realised by other actions and before the intended function is finally achieved. If predictions about the environment of your intended actions fail, scenarios may be useful for design. Scenarios describe possible futures, whether desirable or not. They allow you to check whether your design will retain its desirable value in the different futures that they present. Although this value may be expressed in money, this is not a proper variable for intentional *environmental* diversification.

Public intentions

Intentions differ in the space and time covered. Individual intentions can be unified in a common policy and legislation of a town, a nation or of states united in a parliament. This offers a scale-sensitive variable ranging from private to more public. Public interests, however, largely represent the average of private intentions. Moreover, this variable does not distinguish the majority and the greatest diversity of private interests. There are many more private intentions than there are public interests, and private interests are more diverse.

Solofunctional actions and levels of scale

The private intentions of persons, families and enterprises can cover very different levels of scale. Intentions of a small scale in space often have a small time span as well. They require fewer interfunctional actions. The number of interfunctional actions required for any intention may be an interesting variable. A 'zero-interfunctional' action is any action that immediately satisfies. I refer to these as 'solofunctional actions'. Such actions may show a relationship with the multi-functionality of an environment. A multi-functional environment (e.g. a home) may satisfy multiple needs at once. Interfunctional actions are often specialised within the sequence of actions required to achieve the desired result. They are thus best supported by mono-functional environments that may save time with regard to the more satisfying actions – and the more time that mono-functional, self-satisfying actions take, the better. The question remains, however, 'What is "satisfying"?'

A sequence of functions and intentions

Maslow's theory of motivation[b] offers an interesting 'prepotency' sequence of human needs. This sequence may even apply to policies at levels of scale that exceed personal intentions. The theory comes down to 'physiological needs first' (see *Fig. 44*). If you are hungry, you will forget about any other intention until that need has been satisfied. In order to obtain food, you even may forget safety. Once you are no longer hungry, however, but in danger, your stress will cause you to skip over any intention other than looking for safety.

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[a] Harrison;Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press
[b] Maslow, A.H. (1943) *A theory of human motivation* (Psychological Review 50)50 p 370 - 396

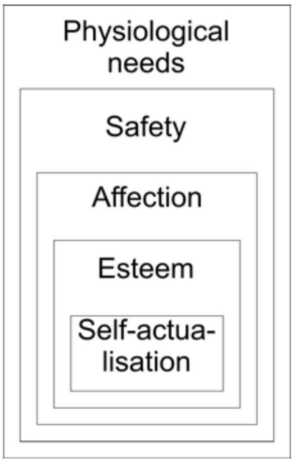

Fig. 44 Maslow's sequence

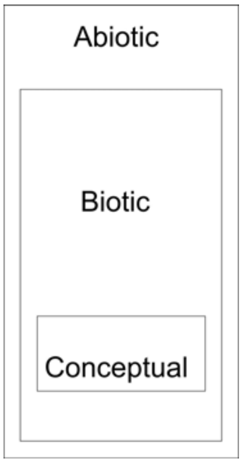

Fig. 45 ABC sequence

Fig. 46 Environmental layers

Even some of your physiological functions slow down while others accelerate in order to prepare you optimally for fight or flight. You even hold your breath while your heart beats. Your home should provide safety first, after which it should afford space for affection, and it could possibly provide you with prestige and self-realisation. It does not matter whether you agree with this Maslow sequence: affection, prestige and self-realisation. Its principle of prepotency can produce a fruitful variable for distinguishing values of intention. Even a national government confronted with hunger, flood or war will stop discussing the taxes, social services, environmental issues and similar topics in order to address the crisis at hand. The theory demonstrates the possibility of a sequence of functions that cannot perform before the previous functions have been fulfilled.

A conditional sequence of intentions

Chapter 6 transforms and extends the prepotency sequence of human needs into a conditional sequence according to a simple 'ABC model' (see *Fig. 45*). This model is useful for distinguishing functions that providing combinations of conditions. A selection of this list provides a summary of successive conditions that an *environment* can fulfil as its 'layers' (see *Fig. 46*). You may recognise scientific disciplines or ministries of a territory-bound government. In all of these sequences, however, any condition requires some fulfilment of the previous ones. The degree of fulfilment determines a 'sufficient level' for the next step. The most urgent motivation or intention thus becomes the next condition of the sequence to be fulfilled, unless a previous condition fails. In such a case, there is a relapse of intention. A previous condition will appear more urgent and gain priority (e.g. more funding).

Multi-functional and solofunctional

What is to be done if the last condition is achieved? A hypothetical environment that fulfils all imaginable conditions is self-sufficient, multi-functional and filled with mono-functional actions (i.e. leisure). There is no need for delay by interfunctional actions and consequently intentions. Such an environment represents a hypothetical zero point of intention, as supposed in spontaneous wild animal life.
Nature might be considered a self-sufficient environment if it were free of human intentions and management (nature preservation). If you consider money as an accepted delay of payment, you can buy time for your interfunctional actions. By employing others, you can fill your time with cultural, managerial or purely mono-functional activity, as if you were living within a self-sufficient environment.

Intentional environmental diversification

How can we distinguish intentional *environmental* diversification? It is possible to imagine two environments that are equal in content, form, structure and function, but still different by intention. At some levels of scale, these environments may have spatial plans. These plans can differ as well. Spatial plans may give an impression of the private or public intention of the environment and the range of interfunctional actions required to achieve the intended use, be it interfunctional or mono-functional at a lower level of scale. Nevertheless, this still does not tell us how we should distinguish intentional environmental diversification if there are no written or drawn spatial plans.

Intentions observable through actions

Intentions become observable through interfunctional actions that end in mono-functional actions. There can be a substantial delay before the mono-functional action appears, and it may have no relationship with the preceding interfunctional actions. Some of the interfunctional actions are paid. Some of these paid interfunctional actions require mono-functional environments. Mono-functional environments may be observable as industrial environments or office environments. Even if interfunctional actions are not paid, you can recognise them by environments that reveal interfunctional actions of traffic and transport. Although interfunctionality may be an appropriate variable for intentional environmental diversification, I fear that I will not be able to provide sufficient answers to the questions posed above.

2.7 Limits of method

Modes of research and study

Possibility search

In the eyes of an empirical researcher, a designer should seem a liar.
A designer draws objects that do not exist. They are not true. They are not even probable. They often fail to satisfy the existing needs, as they are clearly demonstrated by proper empirical research. In some cases, design even seems to *create* needs.

Created needs

'Created needs' (or the deficiencies for which they compensate) may have existed tacitly before. In such cases, design has merely brought them to the surface by revealing new possibilities. If something is apparently not possible, you will eventually stop wanting it after all. You may conceal it as a secret frustration, but you do not express such needs. They sound childish.

Fulfilling tacit desires

When completing questionnaires for empirical research or marketing, you do not enter: 'I want to work magic!' When Steve Jobs designed a magic box, however, everyone wanted it.
No research has predicted that some people would terrorise the world with a knife.
No economic research has predicted that lending money would cause a global crisis.
The usual context that the pledge can be sold if the debt cannot be paid changed. Such improbable possibilities of context-change are usually not included in the rules, variables and parameters of scientific models.
In order to become aware of these possibilities, you must design scenarios, different possible futures, different conditions as input for probability calculations. While models usually take much of the current context for granted, spatial design intends to change it.

Programming and evaluating research

The search for different possibilities calls for another kind of study than is required by the search for general probabilities or even truths. Given that possible futures include the probable futures, this kind of study may *include* empirical results, while exploring a wider field. Its core is even outside the field of probabilities. Its core consists of finding *improbable* possibilities. Probability calculations do not produce designs. Statistical operations can summarise verbally well-defined existing needs. This is known as programming research. Once the design has been made, statistical operations can be used to evaluate its probable effects on the satisfaction of only these needs. This is known as evaluation research.[a]

Means-directed study

Nevertheless, possibility search is not merely aim-directed. Desired functions can still be fulfilled in many ways. Possibility search must select materials (content), their dispersion in space (form), their connections and their separations (structure). These are the design means for fulfilling a function in one of its many possible ways. You must cope with this inconceivable *diversity* of possibilities. You can always make your solution different from any existing solution. If it is not different, it is a copy, not a design. Means-directed search often reveals different, unexpected possibilities that are not represented in any query. What could you do with a touch-screen? What could you do with a knife? What could you do with a pledge? What could you do with a heap of bricks, cement and wood?

The paradox of generalising diversity

A study of possible environmental *diversity* touches upon the core of design (more than simply copying or combining). When confronted with empirical research, however, it

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[a] Jong;Voordt(2002) *Ways to study* (Delft) DUP-Science

encounters a remarkable paradox. Empirical science and the humanities intend to generalise characteristics and rules from as many facts as possible. By doing so, they *reduce* the very diversity that you wish to study. How can you study *diversification* if the existing methods of study *equalise* different cases into a more generally applicable theory? How can you study *environmental diversification* if you must assume that your results are valid only *ceteris paribus* i.e. in a *similar environment*)? This study does not aim to *reduce* the diversity of environments; it aims to discover how to *produce* it.

Diversifying theories

Algorithms repeating the same rule at an ever-decreasing scale (e.g. fractals) or reacting by different rules on predefined environments (e.g. cellular automata, agent-based computer programs) can produce a kind of diversity. This diversity, however, is based primarily on self-similarity or reaction-similarity. It changes (or reacts in) the same single variable (in most cases, colour on a flat plane). The patterns that are produced may remind us of biological or even urban forms, but this has nothing to do with the structural and functional diversification of cells (embryology), the development of specialised organs in an organism (epigenesis) or the selection of species by an environment (evolution). They are determined by many variables at the same time. Repeated application of the same rules may appear in epigenesis and evolution, but it is not their core. Epigenesis and evolution assume that the rules can change upon encountering a different environment. It also includes improbable mutations of the rules, which an environment may or may not accept for survival. The environment selects in the long term, while the organism reacts in the short term.

Evolution as a conditional theory

You cannot simulate an evolution producing the inconceivable biodiversity that we face by applying a few simple rules, however amazing their computed results may be.[a] There is definitely a diversity of rules followed by different species, partly coded in their genes. These rules can also change by accident or upon encountering a different environment. This suggests a rule that rules the primary rules; it suggests a rule of the second order, if such is a rule at all. Evolution theory is thus an exceptional theory. It accepts the influence of an environment and the associated changing rules that are completed by accidental mutations. It thus accepts a kind of conditional thinking. It can clarify the past, but not only by pure causation. It cannot predict, and prediction is usually expected from a theory. For the purposes of this study, however, it is encouraging to note that there is at least one broadly accepted theory that can clarify diversification instead of reducing it. Evolution theory nonetheless *assumes* environmental diversity without clarifying it or telling how to sustain or to *produce* it.

Conditions passed along to other disciplines

Evolution theory takes for granted a necessary condition for biodiversity: the a-biotic diversity and dynamics of the Earth's surface. This condition is its starting point, a hidden assumption. Its clarification is left to other disciplines (e.g. geology and the soil sciences), which subsequently leave some of their crucial assumptions about climatic conditions to climatology. In their turn, climatologists leave their assumptions about climate change to economists and astronomers. Astronomers then pass the ball to physicists who, upon meeting the boundaries of their universe, pay a visit to the Pope.

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[a] Wolfram (2002) *A new klind of science* (Champaign) Wolfram media

Specialised treatment

Something similar may occur if you visit a medical doctor. If your complaints do not fit into any of the diagnoses of your doctor's discipline, you find yourself embarking on a journey along a series of medical specialists, probably ending with a psychiatrist. You are unlikely to be referred to an architect in order to change the conditions that made your complaints *possible* (your chair, your stairs, the ventilation of your room). In the early 20th century, urbanists and civil engineers made the greatest contribution to increasing the life expectancy of urban populations by applying their hygienic measures in cities. Medical treatment added played a much smaller role in the doubling of the life expectancy.[a]

Limits of theory

An empirical theory largely concerns probabilities summarised in a causal sequence. The police may have a theory about the murder, a doctor about the disease, an astrophyicist about the beginning of the Universe. A theory always has a limited clarifying capacity. The police cannot say much about the disease or the doctor about the beginning of the Universe. A theory meets its boundaries in the tacit assumptions about its conditions – and there can be many conditions before an inference is useful.

Cause as the last added condition

Suppose you read in the newspaper that a collision was 'caused' by one of the drivers losing control of the steering wheel. Suppose an extraterrestrial being comes down and exclaims, 'What nonsense! A collision is caused by two objects moving from different directions arriving at the same moment at the same point!' At this point, you must admit that, if the cars had not been moving and one of the drivers had lost control of the wheel, there would have been no collision. If the extraterrestrial being is right, the newspaper must be wrong. It did not mention the preceding conditions of movement, directions, moment and point. It noted only the last added condition (losing control of the wheel) as a 'cause' – and even that was not the real 'cause'. The real cause was the absence of an expected avoidance of the collision by the driver. The driver might even have been planning suicide, and not have lost control of the wheel. Even if you follow the inference of your extraterrestrial being, however, many more conditions will remain to be fulfilled when analysing the movement, directions and so on. Suppose that, shortly before the collision could happen, a tree had fallen down between the cars or that they had lost their wheels, used all of their petrol or developed a malfunction in their motors; perhaps their brakes jammed suddenly. In any of these conditions, there would also have been no collision. These conditions are all very improbable, but they are possible, and improbable possibilities are the object of design.

A design is a set of conditions

The moving of a car without external traction once was very improbable. It was made possible by the design of an appropriate steam engine and, shortly thereafter, the petrol engine. Beyond the development of this engine, however, many other conditions had to be fulfilled (e.g. a steering and braking mechanism, a proper road, a skilled driver). All of these conditions were necessary in order to make an automobile possible. Nevertheless, these conditions were not the *cause* of its motion. A set of *conditions* make its motion *possible*. A cause might have been that someone wanted to drive a car. The design was the set of conditions that made this use possible. Design is a set of conditions, not a set of causes.

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[a] McKeown, T. (1976) *The Role of Medicine: Dream, Mirage, or Nemesis?* (London) Nuffield Provincial Hospitals Trust
McKeown, T. (1979) *The role of medicine - dream, mirage or nemesis?* (Oxford) Blackwell

Research

Solving a problem by removing its cause or conditions

A problem (a probable, but not desirable future) is usually solved by removing its cause. To find the cause, you may need empirical research (probability search). Alternatively, you could also remove one of the many preceding *conditions* that made its occurrence possible. This possibility is often overlooked, as it requires 'possibility search'. If you remove such conditions, or the last condition to be added (the 'cause'), you may disturb more functions than only the problem to be solved. To compensate for these functions, you need an aim (a desirable and possible, but not probable future). To realise this aim, you need a plan for creating the conditions for its realisation (a design). In its turn, however, this aim is also a design. It is an improbable possibility and, as such, it cannot be created by research.

Internal research problems

The *formulation* of the aim of problem-based research also represents a kind of possibility search. The aim precedes the actual research. It is external to this kind of probability search. The aim is derived from an identified external social or technical problem. The research will not solve that problem; it merely searches for its probable cause, usually resulting in advice recommendation to remove that cause. Following this recommendation, a decision-maker can ask a designer to develop a plan for *how* to remove the cause. Such a plan, however, would represent yet another mode (i.e. possibility search). The internal research problems (which could be part of a research proposal) are different from the identified external problem (which could be part of an assignment). Research problems must be foreseen and written in the mode of the research itself (probability search). They analyse the external problem in order to derive a hypothetical but probable cause-effect chain (a theory), which must be tested through research. The summary of what must be checked provides an indication of what must be done (and paid). It may be necessary to check additional theories, or the theory could be branched (if…then…). This would increase the number of cause-effect links in the chains that would need to be checked as separate research problems to be solved. The shift in mode away from a possibility-searching aim definition towards a probability-searching summary of problems you are probably facing in the actual research is not easy.

A second mode switch for the method

Summarising the research problems still does not answer the question of *how* you should cope with these problems. This is a question of method. After summarising the research problems stemming from the aim of the research, you need a research plan (i.e. a 'design' of the research, a road-map). *Met-hodos* is Ancient Greek for 'the way along which'. That also reflects a shift in mode. A method is a *conditional* sequence of actions, not a *causal* one. The previous action does not cause the next action, it makes the next action possible. For example, you can only study data if they are collected first. If the research problems can be solved by usual methods, it is sufficient to name them. If not, you must invent and explain the data in the mode of possibility search. This is easier for designers than it is for researchers.

Design study

An external *field* of problems and aims for design study

In most cases, a spatial-design study does not involve *one* external problem to be 'solved' and *one* external aim to be 'achieved'. It faces an external *field* of connected problems, along with a *field* of aims, as represented by the different possible stakeholders and specialists involved. The translation of the external field of problems according to this field of aims into a summary of design-study problems cannot consist be one-dimensional and *causal*. Such translation requires a 4D *conditional* sequence. It should show spatial possibilities instead of linear probabilities. This summary could be called 'theory' or 'hypothesis', but it is ultimately a design-concept and plan, which must be checked by the stakeholders and the specialists (most of whom are empirical).

A proposal for design study

A proposal for design study should thus contain an overview of these two external fields and one or more design concepts to be checked. It must be checked by specialists with regard to the probability of its desired effects and by the stakeholders with regard to its possibilities. At this point, the actual design study may start, elaborating the concepts, and alternating with internal or external empirical checks. The shifts between these different modes are not easy. It is also not easy to determine the phase in which and the aspects on which it should occur. It is for this reason that evaluation research is so often postponed. Its planning can be a part of your proposal. Such a promise may be more convincing to the client.

Limits of method

The method of design can seldom be explained in advance. There are more methods than there are designers. The method may change during the design process. Although it is sometimes standardised by companies (e.g. in a chain of shops), it is not published in such a way that you can simply refer to it. The method is largely accepted as a freedom for the designer. More methods may produce more possibilities from which to choose. Your arsenal of methods is your repertoire, as demonstrated by your portfolio. It may have been part of the client's criteria for selecting you as a designer. For an empirical researcher, this kind of study is a mess without proper scientific limits. There are limits, however, albeit different from those that are well documented in empirical research.

Limits of scale

First, a spatial design has a scale. Even if your design study does not have a specific location, it still should have a scale. This scale has an upper limit (frame) and a lower limit (grain). You do not design the entire world down to every molecule. To do so would require a drawing much larger than the Earth itself in order to be readable. To fit on your desk, it should be divided into one for a radius of 10 000km, 100 for a radius of 1000km, 10 000 for a radius of 100km and so on, up to 10^{34} drawings for the radius of 1^{-10m}. These drawings must then be multiplied by the number of phases of execution that you promise in your proposal. This process would result in a pile of paper 10^{30} km high. At any level of scale, you will need other legend units, as known from other disciplines (e.g. geography, biology, chemistry). No client would believe you if you were to make such a proposal.

Limits of effort

Even if you only want to study one or more neighbourhoods with a radius of 300m, detailed to the level of a building with a radius of 10m, you would need at least one sketch for the radius R=300m, 10 for R=100m, 100 for R=30m and 1000 for R=10m. This calculation still supposes only sketches. A sketch has a limited level of detail. For example, a sketch may have no grain and precision of location smaller than 1/10th of its frame. You can also make more precise drawings for R={300, 30}, but the effort is the same. However, you do not have to make all 1111 sketches or 101 more precise drawings. You can select several characteristic examples.

Limits of resolution
It may nevertheless be useful to determine these limits more precisely than usual. Do not promise too much. Select a frame and grain that are close enough to each other to avoid piles of paper. Moreover, every intermediate scale range between your frame and grain has its own design means. The legend of a regional plan is clearly different from a legend that would be useful for drawing the interior of a room. A regional plan has no chairs and tables. Although such images may be useful as metaphors for generating ideas, you must still translate them into legend units that are operational enough for evaluation and execution. You can draw a 'window on the sea' for the region of The Hague, but you must still tell what kind of gap in the wall (the dunes) you may intend at a regional scale in order to obtain this 'window on the sea'. Only after you have done this can the specialists evaluate the effects. The civil engineer in your design team will probably warn you about flood.

Effects without limits of scale
The *effects* of the object of your design are not bound to scale. If you want to save energy by design, it may have a global effect.
Although empirical research may study scale-bound objects as well, its samples should stem from a larger scale. The ultimate intention is to draw more general conclusions that are applicable within this larger scale (which is usually not well-defined or limited).

Limits of context
Second, even if the object of your design study does not have a location, it still assumes a context at any level of scale. You may have many tacit managerial, cultural, economic, technical, ecological and spatial suppositions about these contexts at different levels of scale. You may assume that the national legislation (or any decision-maker or manager) will accept the kind of design that you are going to study. You may assume that the neighbourhood will like it, that there are clients or users who need and can afford it, that it is technically executable, ecologically favourable, and that there is sufficient space, time and material to realise it. If these assumptions do not hold, there is a problem to be studied.

Limits of levels and layers
At each *level* (e.g. nation, region, town, neighbourhood), however, each *layer* of these contexts (managerial, cultural and so on) may limit the possibilities of your design object. It is useful to make these possibilities explicit before you start the actual study. You can include them in your proposal, where they could generate the probable set of problems the proposal must solve. They could generate the desirable set of aims (i.e. a desired future or, even more precisely, a program of requirements) that the proposal must fulfil.
You tacitly assume that your object of study will create possibilities for meeting all of these problems and aims. In different stages of your study, they will be checked by managerial, cultural, economic, technical and ecological specialists and stakeholders. You would nonetheless do well to question whether all of these possibilities are equally relevant within the case you are going to study. How should you balance them in order to determine which stakeholders and specialists you wish to be present in your team?

Limits of impact
Before you start the actual design study, and even before you have determined its object, you can clarify the effects of this assumed object. It concerns the effects that you *wish* to achieve, as well as the effects that you may *expect*. These are substantially different. The first kind of effects belongs to the desirable future, while the second kind belongs to the probable future. By making them explicit in advance, you can clarify the field of problems (probable but not desirable) and the field of aims (desirable and possible, but not probable) of your study. This largely requires you to be explicit about the future context of the design object you are proposing. This could have many immediate advantages for your proposal.

- Such specification protects your study against evaluations that contain other assumptions about the future context.
- It raises awareness of the robustness of the object in different future contexts.
- It makes the results of your study comparable to other studies in similar contexts.
- It raises a proper 'field of problems' to be solved in a design concept, instead of presenting an empirical summary of isolated problems that neglects the side effects of their separate solutions.

The context of an impact

The impacts of a design object depend upon this context. If the municipal management has a traditional culture, but your client is open to experimentation, an experimental design will have a different effect than it would in the reverse case. Once you have made that context explicit, you can estimate the effects that your object of study may have, as well as the problems you may encounter. You still need not be explicit about the actual impacts. It is sufficient to estimate the level and layer of the context at which the effect can be expected.

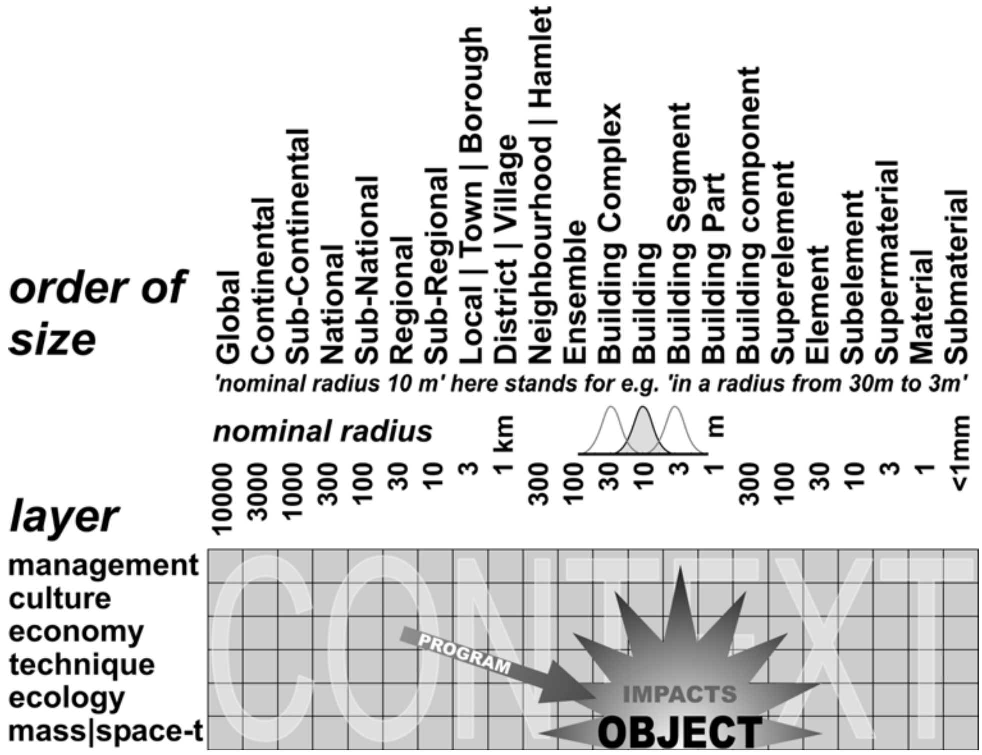

Fig. 47 A matrix of levels and layers of context

This has a number of additional advantages.

- It indicates the kind of stakeholders that may be willing to pay for the positive effects.
- It could produce a field of aims that is broader than those specified in the client's program of requirements.
- It makes you aware of problems that could cause negative effects.
- It indicates the kind of stakeholders and specialists that you need in your team.
- It clarifies your personal interest in and fascination with determining the object of study.

All of this can be accomplished before you have even chosen the actual object .

A matrix of an object and its context

You can simply create a matrix of possible context levels and layers (see *Fig. 47*). You may change their categorisation and limits). Determine the grain and frame of your proposed object, and begin by placing it in the lowest layer. A spatial design should have mass, take up space and remain in place for some time. Be sure to position it within a limited range of scales, thereby limiting the number of drawings you will have to make or to study, thus reducing your effort and the cost of the project. Beyond the object, the rest is context.

Intended and necessary impacts

During the period of its existence, the object will have impacts at other levels and layers of this context. Some of these impacts are so positive that a client will be willing to pay for them. Clients may express their desires in a program of requirements. Nevertheless, you may anticipate additional positive effects and – in all honesty – some negative effects as well. Place plus and minus signs where you want or anticipate them. This will locate the field of aims and problems of your study. Do not put too many of these indicators in the matrix, as this will lead your client to expect reports on all of them. Write down your hopes and fears for every plus or minus.

The future context determines the impact

Once you have *located* the effects in the matrix, you can elaborate their *character*.
The effect of your object in any cell of the matrix, however, depends upon its future *context*. Which context might you implicitly expect there? In order to make this probable future context explicit, you will need an identical second matrix in which to notate your expectations. You need to be explicit only in the cells in which you predicted any effect in the first matrix. At the layer of management, you may place exclamation points or question marks (!,?) at levels at which you anticipate either active management (full of initiatives) or management that waits and checks only whether your initiatives conform to the law and current policy. The effect of your design object may be very different in these two cases. At the layer of culture, you may choose between experimental (>) or traditional (<). At the economic layer, you may distinguish between expected growth (+) and decline (-). At the technical layer, you may distinguish between apparent combination, connection (x) or division, separation (/) of functions; at the ecological layer, between an expected process leading to more diversity (|) or more homogeneity (=) of the population or its habitat; and at the layer of mass and space-time, between concentration (C) and de-concentration (D). For example, urban ensembles may show an accumulation of buildings (C_{100}), which are nevertheless dispersed spaciously throughout a neighbourhood (D_{300}), thus providing many open spaces at that level.

Scenarios of probable and desirable contexts

What you have done in the process described above is nothing other than creating a scenario and an impression of the probable and desirable impacts of a possible object within that scenario (see *Fig. 48*). You can create additional scenarios (see *Fig. 49*) in order to determine the ‘robustness’ of a design in different situations. A ‘robust’ design performs well in a variety of different scenarios. If you make an office building in a period of economic growth within the municipality in which it is located, it is ‘robust’ if it can change its function in periods of decline. This may be included in the broader program of requirements for the object, which your client may have forgotten. By creating such scenario matrices and determining the impacts of a designed object, you limit the field of problems and aims for your design study. The field is still less limited than a clearly defined problem for an empirical study aimed at finding a cause. Empirical research is less context sensitive than are design studies involving a single object that has yet to be designed within a given context. The empirical study requires a sufficient number of similar objects in order to justify more general conclusions at a larger scale. It accepts a *ceteris paribus* assumption that a design study cannot afford.

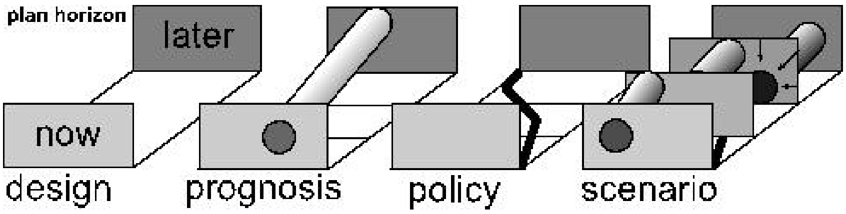

Fig. 48 Possible, probable and desirable futures in a scenario

Fig. 49 Four scenarios on 2 x 2 alternatives

Object and context in design-related study

If you study existing designs, call it research. Otherwise, call it study (see *Fig. 50*). Evaluating the probable impacts of an existing design within a given context is design research. Comparing designs in different contexts and searching for means of design is typological research. In this case, you may find 'types' that are apparently applicable in different contexts.

		OBJECT *Determined*	*Variable*
CONTEXT	*Determined*	Design research	Design study
	Variable	Typological research	Study by design

Fig. 50 Context sensitivity of design-related studies

Use the term 'study', and avoid the term 're-search' if the actual design has not yet been determined (i.e. if it has yet to be designed). In this case, there is no existing physical subject of research. If a context has been given, however (as intended in the previous paragraphs), call your work a 'design study'. In this case, the context is the logical starting point for limiting this kind of study, as you apparently have nothing else. The way in which you can accomplish this is described above.

Study by design

Study without a determined object or context

What should you do if you have no physical object and no context ('study by design' in *Fig. 50*). For an empirical researcher, this sounds bizarre. How can you start a study without a subject and even without a context that could provide a problem and an aim? It has no limits. This kind of study resembles that which empirical researchers scornfully call 'a solution looking for a problem'. It is this precisely this type of study, however, that has produced great inventions with great impact. Instead of starting with the aims, it begins with the means. Means-directed study (or 'study by design') still does not solve any existing problem. The problem is an open question. What could you do with steam, electricity, semi-conducting materials, glass, brick, concrete? The only aim is to have fun or to satisfy curiosity. It is not immediately a question of how you can *use* it, but how it behaves in different contexts, which forms and structures it can take, or what its *possibilities* are.

Black holes

On the other hand, study by design *seems* to have no object and no context. Thus far, 'design' has always assumed a physical object with a form and a structure (if not actual, then at least possible). This is a hidden assumption, however, developed within the previous context of this thesis. Electricity may also have no immediate form or structure, but it does have an observable behaviour (i.e. a 'function' in a sense that extends beyond 'use'). Before you actually know what it is, 'something' may exhibit interesting phenomena that can be studied. If you experience attraction and observe sparks as soon as you rub a piece of amber, you may develop theories about the phenomenon. Can pieces of amber burn through the heat of rubbing, producing sparks? What is then the source of the attraction? Although you may conceive of a mysterious subject of study and call it electricity, what you observe is attraction and sparks. You observe a peculiar behaviour between the amber and a piece of cloth after rubbing. You may try to achieve the same result with other materials, rubbing the amber in other contexts (e.g. under water, in moist air, in other gasses, in a vacuum, with or without light, noise, wind, or when thinking about something). You perform experiments. You perform experimental study without a determined subject. After all, the subject is observable only through its behaviour. Many even more abstract subjects have been named and studied in a scientific way, observing only a behaviour or a function.

Useful imaginary objects

As the story goes, Newton saw an apple falling, thereby exhibiting a force equal to its acceleration times its mass. He could not observe the actual force, but only its effect: the impact in the grass. He simply conceived of something pushing or attracting *outside* the apple and called it 'force'. He did not see 'acceleration' either, only the falling behaviour of the apple. He even did not observe the 'mass' of the apple, which he conceived as an internal feature. He only could only see its size and feel its weight. Its weight, however, was apparently not the mass itself, but an *external* force, which pushes more or less *on* your hand. This 'more or less' may *depend* upon some internal feature of the apple (or of any other physical object), but it is not that feature itself. The mass of the apple could also not be its size, given that a cannon ball of the same size weight more than an apple. Newton referred to this imaginary internal feature as 'mass'[a] and made it a subject of study along with the other properties. However imaginary, he was able to *quantify* these virtual

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[a] He should have known that mass does not influence acceleration. Already a century earlier, Stevin had climbed the slanting tower of the Old Church in Delft (Netherlands) and dropped two cannon balls of different weight. He could not hear any difference as soon as they reached the ground. In his experiment, he by-passed 2 000 years of superstition, since Aristotel had claimed that any object itself has a 'will' to fall. This locates the force inside the object. It is thus inconceivable as something separate from its internal mass. Galilei published these findings 30 years after Stevin climbed his tower, although he probably never climbed the tower in Pisa, as another story goes. He also bought a telescope in Middelburg (Netherlands) as soon as it had been invented there. He then discovered the phases on the moons of Jupiter and gained some understanding of their continuous circular 'falling', which balanced the centripetal forces and gravity.

'subjects'[a] and even to measure some of them. He created a mathematical function using these subjects as variables. He connected the variables in a theory, which was probably useful in the wars of England when applied to cannon balls.

Pragmatism and possibility
Since the time of Newton, the scientists of the Anglo-Saxon world have largely been 'pragmatists', as Peirce[b] called them later. According to pragmatists, 'True is what works'. If you can win the war by using a nuclear bomb, Einstein's theory that mass itself can be converted into energy must be true. Although Europeans questioned the actual 'existence' of Newton's subjects of study, I still do not know (or understand) their answer. In my opinion, their existence is *possible*. Leibniz, quarrelling with Newton about their simultaneous invention of infinitesimal calculus (which is required in order to calculate the falling of apples and moons), was the first to understand the utility of possible worlds for understanding the actual world[c] as one of the *possibilities*. Over the course of more than two centuries, however, everybody forgot this insight, until Lewis demonstrated how to cope with them in the context of formal logic ('modal logic').[d]
I nonetheless have doubts about the appropriateness of the right context.

Theories useful for design
Anyone who draws a building in perspective knows how useful vanishing points can be. Although they do not 'exist', they *could* exist as towers on the horizon at the end of the crossing roads lining the buildings. You draw them to reconstruct a realistic impression. A 'theory of perspective' demonstrates the *possibility* of drawing many buildings in different positions. A camera uses a construction of lenses based on a different theory, but with the same result. A camera, however, cannot choose the location of the buildings. Different theories have different limitations. A theory is a construction intended to show limited possibilities. It connects and separates earlier impressions in a particular way. It structures them. The remaining possibilities must be checked through experimentation.
For example, a detective may have a theory about a crime. It may be simulated on location in order to conduct closer examination and in order to determine whether it is possible at all. Could the armed criminal see the victim from that position, shoot the victim there and fly by in a car without being noticed? That experiment may change parts of the theory. The criminal may have used another position and another road. Has anybody seen a car parked there in the hours before?

Theory is an eye
Theory is an eye, a means to see things upon closer examination. At the same time, it is also a hand, convenient for planning, designing or making things. The criminal once had a plan as well. He or she may also have visited the location before. There, the criminal may have checked whether the plan would be possible at all, just as designers do. Nothing is more practical than a good theory. A bad theory is dangerous, however, even if it seems to have worked so well so often. Economic theories seemed to work so well – until the crisis came.

Variables and legends of a drawing
Any theory relates categories (e.g. mass and acceleration with force, vanishing points with lines in a drawing, the possible positions of a criminal with those of the victim).
If a category (a set) can acquire a well-defined sequence of its values (i.e. elements of the

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[a] Newton(1687) *Philosophiae naturalis principia mathematica* (Internet) http://members.tripod.com/~gravitee/
[b] Peirce(1992) *Deduction, induction, and hypothesis* **IN** Houser, N.; Kloesel, C. *The essential Peirce* (Bloomington) Indiana University Press
[c] Leibniz(1710) *Theodicy* (London 1951) Routledge & Kegan Paul Limited http://www.gutenberg.org/browse/authors/l
[d] Lewis(1918) *A survey of symbolic logic* (Berkely) University of California Press http://archive.org/details/asurveyofsymboli00lewiuoft
Kripke(1976) *Naming and Necessity* (Oxford 2007) Blackwell
Divers(2002) *Possible worlds* (London, New York) Routledge

set), it is called a variable. 'Well-defined sequence' thus means that the differences between subsequent values are of the same kind, albeit smaller than the differences between any pair of non-subsequent values. The kind of difference can be nominal, ordinal or quantitative.[a] A theory is limited by its chosen variables, although the 'choice' of values within each variable remains free. In a drawing, the *legend* may represent one or more of such *variables*. The legend *units* represent their *values*. The gaps in the theoretical sequence of a variable (values never observed before) may indicate new *possibilities*. As a kind of study by design, you can search for the possibilities (still limited by the defined variable) of intermediate values as new legend units. You can even search for new variables by making new legends. Both produce new possibilities or means for design.

Disturbing the sequence by design

Empirical data are usually ordered in a well-defined sequence. In a drawing, however, the values may be accidentally adjacent. If $\{x_1, x_2, x_3 \ldots. x_n\}$ are the values of a variable x in a well-defined sequence 1, 2,…n, the legend unit x_3 may still appear next to x_{16} in a drawing. For example, European statistical data about branches of business are ordered as follows:[b]

A - Agriculture, forestry and fishing
B - Mining and quarrying
C - Manufacturing
D - Electricity, gas, steam and air conditioning supply
E - Water supply; sewerage; waste management and remediation activities
F - Construction
G - Wholesale and retail trade; repair of motor vehicles and motorcycles
H - Transporting and storage
I - Accommodation and food service activities
J - Information and communication
K - Financial and insurance activities
L - Real estate activities
M - Professional, scientific and technical activities
N - Administrative and support service activities
O - Public administration and defence; compulsory social security
P - Education
Q - Human health and social work activities
R - Arts, entertainment and recreation
S - Other services activities
T - Activities of households as employers; undifferentiated goods (and services)producing activities of households for own use
U - Activities of extraterritorial organisations and bodies

You may question whether it is a well-defined sequence. Even if it is, your examination of a map may reveal more different neighbours than any sequential pair. For example, you can find a manufacturing business (C) next to an educational institution (P). If 'Branches of business' with values {A…U} is assumed to be a variable, the difference between C and P is assumed to be larger than the distance between C and D. Be that as it may, what *kind* of difference has determined this sequence? Is it relevant for the design of a school next to a manufacturing business or for the design of a neighbourhood at a larger scale and with more kinds of business?

The kind of difference covered by a variable

Many differences are relevant for design. Examples include the number of employees in each company, the number of visitors (dispersed throughout the day) and their economic

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[a] Stevens(1946) *On the theory of scales of measurement* (Science)103 p 677-680
[b] http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

value or nuisance to the environment (at different levels of scale). By sorting variables according to these characteristics (differences), you can create new variables (e.g. 'number of employees per company' and 'amount of nuisance per company'). Relating these variable on an xy graph may reveal a relationship – an empirical theory – although this still does not solve your design problem. What you can locate next to what, and how many parking places will you need? How you can add or avoid functions in order to achieve synergy?
Some differences (e.g. the amount of nuisance) appear to be relationships in and of themselves, even if they are presented as empirical values (e.g. 'the average nuisance of x'). Nuisance, however, is always a nuisance *of* x *for* y. You can thus create a matrix containing the list of companies {A…U} on both the horizontal and vertical axes, thus producing a 21x21 matrix. One of the cells will report the possible nuisance of a school for the manufacturing company, while another cell will report the reverse nuisance of the manufacturing company for the school. Although such a matrix could be useful for design neighbourhoods, they are seldom used. You may ask, 'Why not?' The answer is that such matrices can raise a multitude of doubts and questions.

Inward averages useless for design

The values above still contain very different kinds of companies, and the levels of nuisance reported between are averages, which are useless for design. The branches of a company may be subdivided much further than shown above (actually some 1 000 branches), but that would require a matrix of 1 000x1 000. Even then, the matrix would report averages that would probably not fit the particular school and particular business at hand. For the design of a particular school, the kind and amount of nuisance should be specified (e.g. noise, odour, risk), in order to determine whether some of these kinds of nuisance can be easily mitigated by the actual design as an improbable possibility. Outward averages within the grain of design, which are not involved in the actual design (e.g. the pressure tolerance of brick or the stress tolerance of steel), are useful for design. Many inward averages (e.g. climate, demography, available technology, economy, culture, management) are also useful for determining the context of design. In contrast averages at the scale of the actual object of design are not useful. If design searches for *improbable* possibilities, statistics and calculating probabilities are unlikely to help the design. They could perhaps be useful as a motivation for *deviating* from the reported average.

A search for variables and their values

Empirical research and design nonetheless share a common concept: the variable. Variables can be used to search for probabilities *and* possibilities. Suppose you observe a building with a garden and you want to study it. An empirical approach could then be to define 'building' and 'garden', to collect more cases of that combination, to select an appropriate number of measurable variables and to look for similarities in their relationships, in order to generalise them in a theory. It is unclear, however, how you could use variables in design studies.

A search for differences

You could start by asking yourself what the *differences* are, even in that singular case. You may discover such contrasts as stone/soil, built-up/green or closed/open. You could then try to imagine something designable between these extremes (e.g. stone/*gravel*/soil, built-up/*pavement*/green, closed/*covered outside space*/open; (see *Fig. 51* 1). In doing so, you would thus *create* variables that could possibly be useful for research and design. Nevertheless, the variables mentioned here, still have no more than three values.

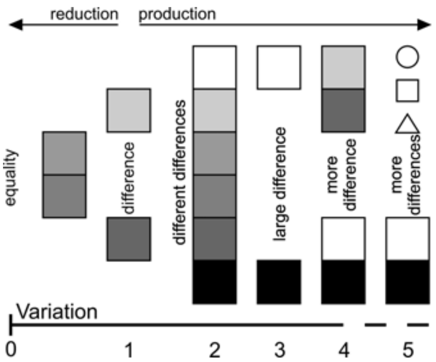

Fig. 51 Searching for differences

radius in m	built-up / green	built-up / water	built-up / pavement	green / pavement	water / pavement	green / water
30 000	national sprawl	building at the coast	mainports	green lay-out of highways	Afsluitdijk	Waterland
10 000	green heart	dream of the estate agent				Casco-concept
3 000	bufferzones				Tjeukemeer	3 networks concept
1 000	urban green		noise nuisance	roadside maintenance	harbours	bank recreation
300	district green		opening-up		boulevards	
100	neigbourhood green				quays	
30	ensemble green	drainage				slope
10	court or garden					
3	fragmented green	Venice	building line			
1						campsheeting

Fig. 52 …,their possible borders and design problems

Try to find more intermediate values (see *Fig. 51* 2) and draw them. Then look for extremes (see *Fig. 51* 3).). Is there something more built-up than the built-up area that you see? You may conclude that there are grades of built-up between one-storey and high-rise buildings. Extend your variable. Is there something greener than the green you see? You may conclude that there are prairies and tropical rainforests, with many green environments in between. You may also conclude, however, that a tropical rainforest is the greenest environment on Earth. You found a zero-point. Now you can give your variable a name. If you cannot find one, do not choose the zero-point, but the other extreme: ‘built-up’.
I must now mention a point that I have previously neglected: at which levels of scale are these variables able to be designed? The variable ‘built-up$_{10m}$’ may receive a different meaning from ‘built-up$_{10km}$’. Reformulate the intermediate values for any scale, if necessary.

Improbable relations

Empirical research searches for probable relations between variables to get a more generally applicable theory. I suppose that the majority of cases of buildings with gardens would demonstrate a strong relationship between the variables you found. Nobody would be interested in such results, however, if they are self-evident.
Design produces *improbable* relations. Could you imagine a reverse relation? Could you imagine ‘built-up’ connected with ‘soil’ and ‘green’ with ‘stone’? Draw green walls and roofs, deviating from the average relation. Add other variables drawing them. Check the possibility of other improbable relations beyond the well-defined sequences of the variable (see *Fig. 51* 4). If they seem impossible, determine whether you can imagine borders, separating or connecting devices in between, structures making their mutual exposure possible. These constructions may be smaller than the differences they bridge, forcing you to detail them. Determine their operational scale. Identify the design problems for each radius (see *Fig. 52*).

Searching form variables of a second order

By drawing any of these differences, you were forced to provide them with a form. Distinguishing the same difference, you could have chosen another form from the many possible forms. Built-up and green may have been be separated by a straight, curved or vague line (see *Fig. 53*). ‘Vague’ lines are discussed later. ‘Straight’ and ‘curved’ are already values allowing many intermediate values. ‘Straight is a clear zero-point, ‘curved’ can always be more curved. Then ‘form’ may have a variable itself. By assigning form to the difference, however, you have added a second kind of difference (see *Fig. 51* 5 superimposed upon the kind of differences discussed so far (e.g. ‘built-up’). That content ‘takes’ form. Moreover, without content (i.e. without a difference between black and white in *Fig. 53*) there is no form. Form thus produces a ‘second-order variable’. Perhaps there are more variables of form that have yet to be distinguished.

Fig. 53 Straight, curved, gradient

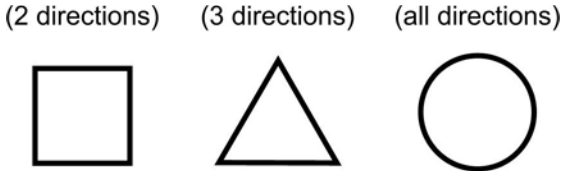

Fig. 54 Paralellogram, triangle, circle

Diversity of direction

If your drawing shows a first order difference into all directions, then you made a shape with a 'contour'. This contour itself requires at least two directions in order to make a difference between inside and outside. Alternatively, you could also have done it using three (triangle) or more directions (see *Fig. 54*). 'Contour' is another appearance of form. 'Direction' is apparently an important characteristic of contour. A contour has a direction and a difference perpendicular to that direction. This is implicitly supposed in *Fig. 53*, which shows only one arbitrary direction of difference. It is explicit, however, in *Fig. 54*, which shows all directions. If you take 'change of direction' as a variable, *Fig. 54* acquires a reverse sequence. The circle has only one change of direction at its contour, a triangle three and a parallelogram four. Which variable shall we take?

Simplicity

Although 'change of direction' seems more complex, it is more tangible in our daily experience. Perhaps 'direction' is not so simple a concept as we suppose. You need a standard direction (e.g. 'North') and a standard angle with which to define it. 'Change in direction', however, compares two directions by itself. You can talk about 'more and less' change in direction. It has practical consequences at different levels of scale. A ball is smoother than a box, safer for children and easier to use as a football. A roundabout requires less interaction with the steering wheel of your car. The steering wheel determines the change in direction, not the direction itself. A circle has a shorter length than any contour surrounding the same surface. A circular building, however, may require additional constructive efforts. A constructor prefers a minimum of directions, but I would prefer 'change of direction' as a variable of contour, or even better: 'adjacent difference of direction'. 'Change' supposes a movement along the contour. Moreover, 'change of direction' could then be used to indicate a change in the contour as a whole.

Form as a state of distribution

The form of a town seldom has a clear-cut boundary or contour. Its boundaries often have the character of a gradient, as shown in *Fig. 53*. The built-up area is dispersed differently across the area. Nevertheless, it still has something that you may call 'form', which is different from other towns. A gradient nevertheless shows an infinite number of intermediate values. You cannot name them all separately and use them in a lengthy legend.
The usual solution is to divide the values into classes of density, assigning each class a colour and a contour in the drawing, as altitude lines in a map. This solution, however, hides the true *form* within each class. The contours depend upon arbitrarily chosen class boundaries.
A better solution would be to draw dots at a size representing an actual quantity, such as the standard population (see *Fig. 11* on page 45) or the surface of built-up area (see *Fig. 15* on page 46). Understood as 'dispersion in space', 'form' has many advantages over 'contour', but you are accustomed to drawing lines. The dispersion of people in space thus also acquires a 'form' (see *Fig. 55* representing a surface of 300m^2 urban space/person in any dot of 100 000 or 10 000 inhabitants and *Fig. 56* 30m^2 floor space/person in dots of 1000 inhabitants). The dot-map representation can be used at any level of scale, and not only for people/surface as a variable. It can be used for other variables as well (e.g. built-up area, employees, capital, trees, parked cars). Statistical data obtain a dispersion in space, a form.

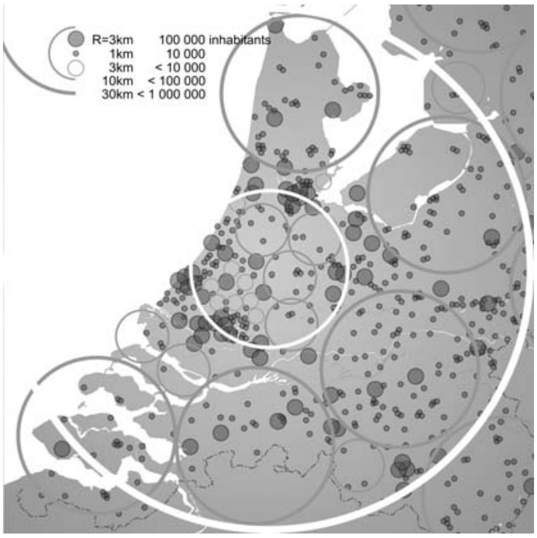

Fig. 55the Netherlands R={100, 30km}
10^5 and 10^4 inhabitants/dot
($300m^2$ urban space/inhabitant)

Fig. 56 The Hague R={10km, 3km}
10^3 inhabitants/dot
($30m^2$ floor space/inhabitant)

Diversity of distance

An old-fashioned printing pattern of different-sized dots at the same distance in a grid clearly proves that such a representation can show a form accurately (see *Fig. 57*).
It includes both sharp contours *and* gradients. The Dutch artist Peter Struycken used a representation with the same results by applying dots of the same size (see *Fig. 58*). This technique uses their mutual distance to determine the density (or, more precisely, the distribution) of dots. If you use dots to represent a quantity, a computer can count them, thus producing the density for any surface within chosen boundaries.

Dutch stamps
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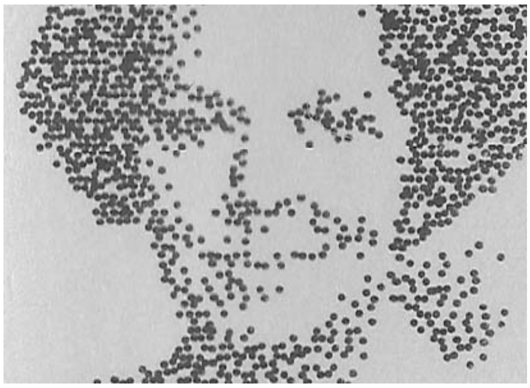


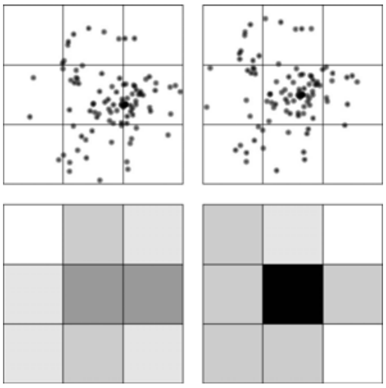
Fig. 57 Different size, same distance

Fig. 58 Same size, different distance[a]

Dot maps for research

In 1854, the famous physician John Snow used a dot map to find the cause of a cholera epidemic in London. He dotted the cases in a drawing (see *Fig. 59*) and discovered that they were concentrated around a water well. He then suspected this well as the cause of the disease. This discovery caused a revolution in medical thinking about epidemics and infection. It clearly shows the advantage of dot maps for empirical science as well.

[a] Peter Struycken



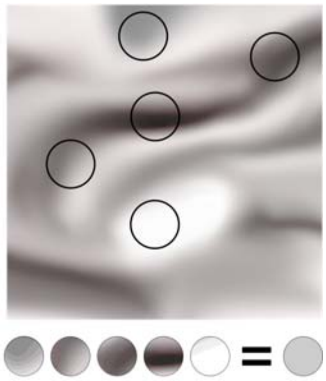


Fig. 59 Snow's map R=300m[a] *Fig. 60 Reductions in GIS* *Fig. 61 Reducing gradients*

When generalising such data in a GIS application, however, the grid may reduce the same dispersion in different ways (see *Fig. 60*). It depends on the location of the grid and the classes chosen. It hides the form. A higher resolution could reproduce the form (see *Fig. 57*), but this would requires precisely located data, and it would reduce the speed of calculation. Moreover, reduction into averages too large for distinction may cause gradients to become invisible (*Fig. 61*).

Dot maps for design

The use of dot maps for design and planning has great advantages. *Fig. 62* shows an example of four alternatives for 50 000 inhabitants, drawn in 50 added dots of actual size. This type of map is easy to draw and useful for traffic engineers, shop planners, ecologists and other specialists to evaluate a design concept in its first stage. Dot maps are a bridge between design and empirical data.

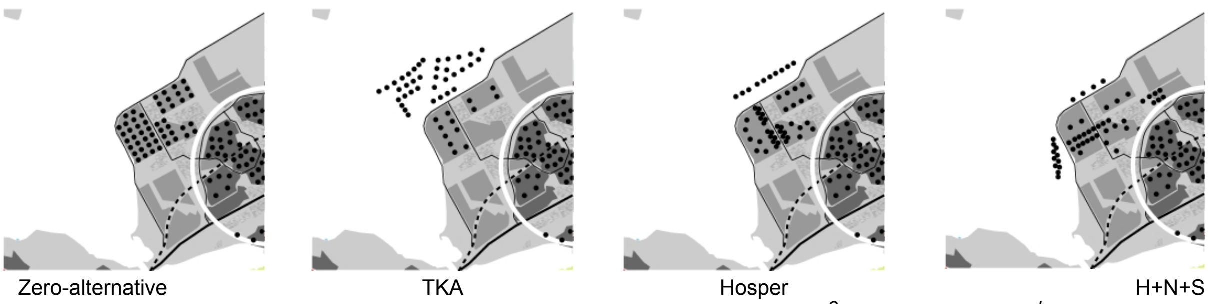


Fig. 62 Alternatives for 50 000 inhabitants in Almere R=3km, 10^3 inhabitants/dot[b]

Beyond the detailed data the plans of *Fig. 62* also have a compositinion with distinguished components. If you look at *Fig. 57* and *Fig. 58* at some distance, you can immediately distinguish a face, a neck, hair and background as *components* of a symmetric *composition* at a larger scale. At this scale, the same image still shows other differences.

[a] http://en.wikipedia.org/wiki/1854_Broad_Street_cholera_outbreak
[b] Jong (2001) Ecologische toetsing van drie visies op Almere Pampus (Zoetermeer) MESO

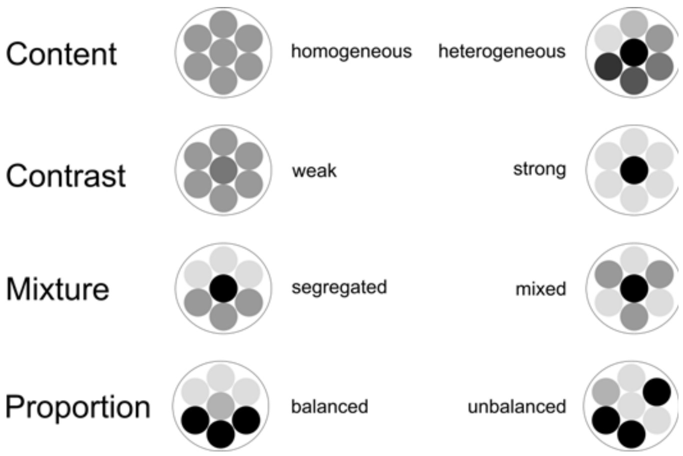


Fig. 63 Variables of composition

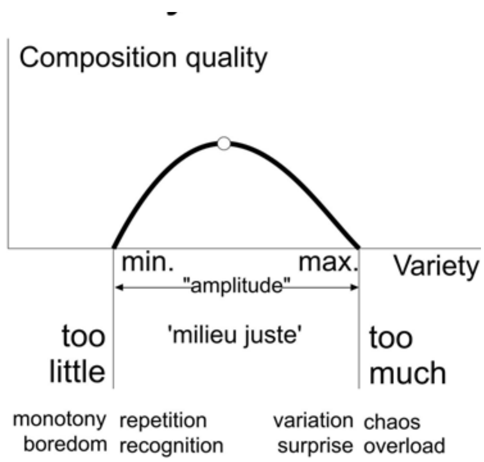


Fig. 64 Quality between recognition and surprise

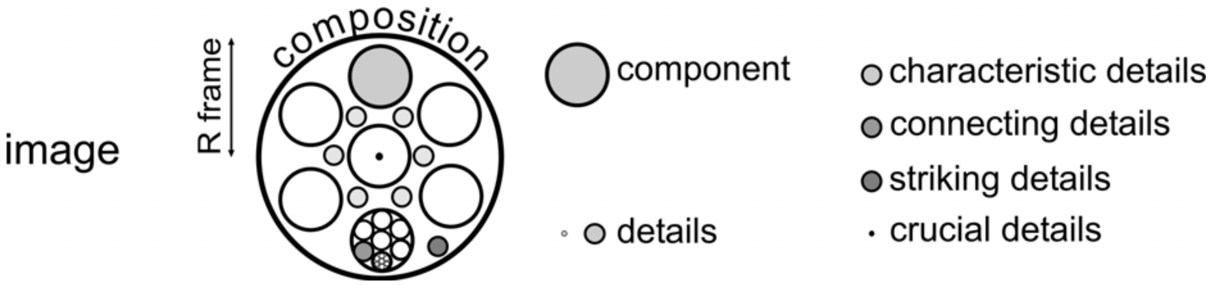
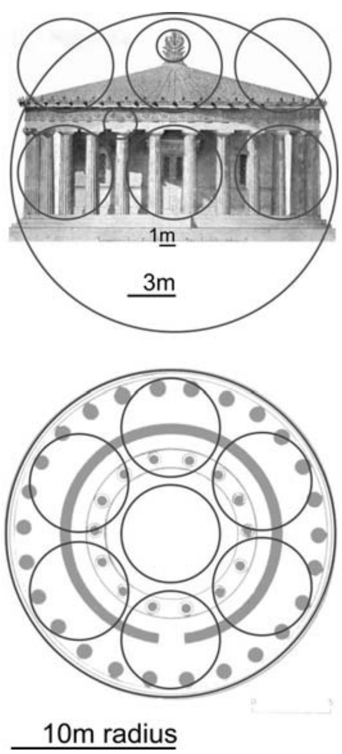
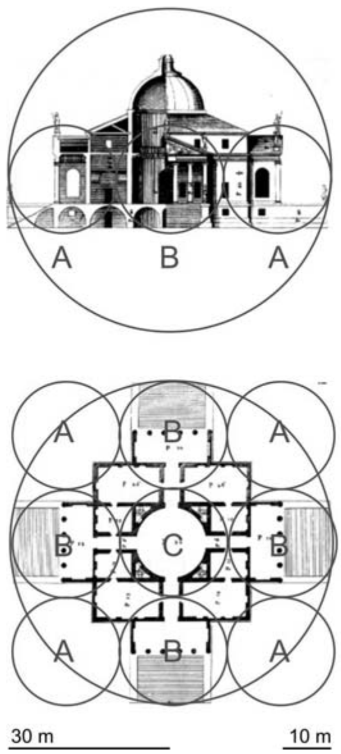


Fig. 65 Composition, components, details



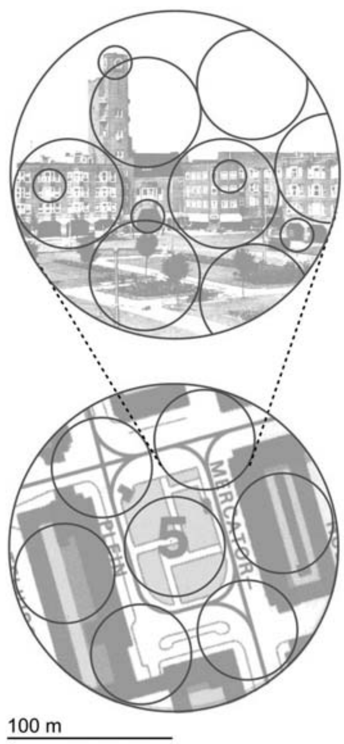
Tholos of Asklepios, Epidauros

Fig. 66 R=10m composition



Villa Rotonda (Capra) Palladio, Vicenza

Fig. 67 30m composition



Mercatorplein, Amsterdam

Fig. 68 100m composition

Diversity of composition

A composition may have a homogeneous or a heterogeneous content, components with weak or strong contrast, segregated or mixed mixture, or balanced or unbalanced proportions (see *Fig. 63*)). All of these variables contribute to its variety. Too little variety is boring, while too much variety gives a chaotic impression. Between these boundaries, the ‘quality’ of a composition is determined by a balance between recognition and surprise (see *Fig. 64*). In addition to the *components*, however, smaller details substantially contribute to a composition. They belong to the composition and relate it to a lower level of scale (see *Fig. 65*). You can distinguish four types of details:

1 *Characteristic* details showing repeating features *within* a component,
2 *Connecting* details transitional *between* components,
3 *Crucial* details with the same impact as a larger component,
4 *Striking* details, an accidental ‘label’, not really a part of the composition.

Compositions of different scale

You can recognise such components and details at any scale (see *Fig. 66* - *Fig. 68*).These figures use non-realistic standard circles for components of different size and form in order to maintain a distinction between components and details in its legend of *Fig. 65*. They fit relatively well in *Fig. 66* and *Fig. 67*. On the other hand, *Fig. 68* shows how standard circles can also suggest smaller and larger ‘real’ components through their overlap or separation. The ‘real’ components often have vague boundaries with transitional zones. Different people will separate them differently. Any attempt to delineate them more precise in a drawing is unnecessary, however, if a standard circle shows their location and roughly their size, leaving some freedom of interpretation with regard to their boundaries.

Visual and real structure

Due to the structure of your eyes, your field of vision has a clear central focus and a vague outer boundary. With this field, a central component may be more clearly distinguished than peripheral ones are. Rapidly shifting your focus, you try to comprehend objects as compositions containing central and peripheral components and details. A painting with a clear frame helps to limit your attention. It separates the composition intended by the painter from a further context. If it is a large painting, you can look more closely in order to discover smaller compositions, thus framing them yourself. If you refer to a set of separations and connections as ‘structure’, the ‘structure’ of a 2D visual *composition* is something other than the structure of mechanical and functional connections and separations that constitute a 4D reality. If a 3D object remains stable in this changing reality, it offers you the possibility of obtaining infinite alternative and repeated views from different positions in order to *construct* a 3D image. In order to obtain 4D insight into the connections and separations that keep the observed components together, however, you will need even more impressions and even closer examination. At one time, you may have discovered that the scenery in a theatre has another construction than the same scenery outside the theatre. If you wish to restore old buildings, you may change their internal structure in order to preserve the external form. The same external *form* may thus have different *structures*. Environmental structure may thus differentiate through its own variables superimposed on its morphological diversification. This structural diversification may subsequently have independent variables of a third order.

Searching for structure variables of a third order

‘Structure’ is defined as the ‘set of connections and separations stabilising a form’. You have repeatedly received equal impressions of a form so often that an independent external reality has become more than probable. Environments with an equal form may nonetheless have a different construction or structure. An image or a souvenir copy of the Statue of Liberty looks like the real one, although they clearly have a different structure (see *Fig. 69*).

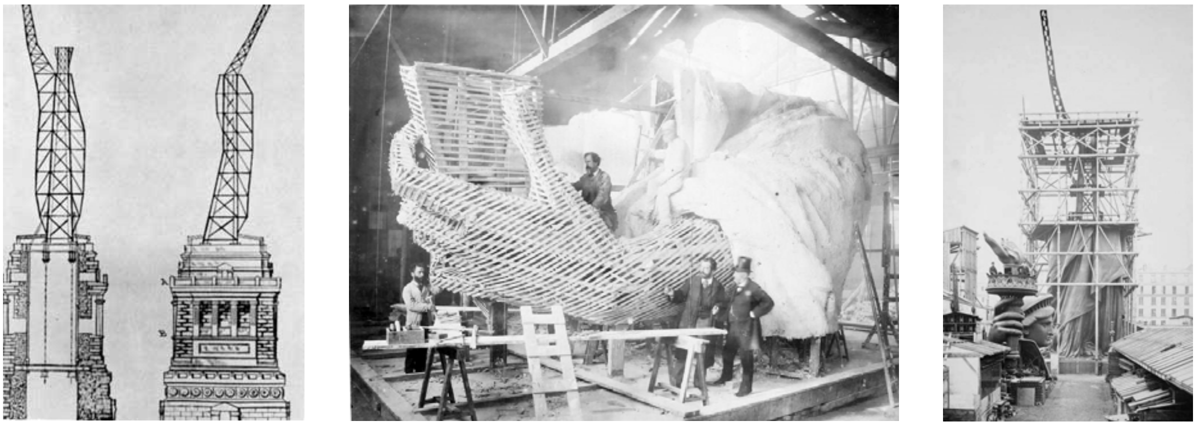


Fig. 69 The New York Statue of Liberty constructed in Paris 1884[a]

Any structure should have a distribution of its connections and separations in space, a form. It assumes ‘form’, but the external impression may have a different form and character. They may sometimes appear as *connecting* details in the impression of a composition, although they may *separate* in a mechanical sense. A column resists pressure; a wall resists energy flow. The components of a composition may be *separated*, but the structure may unveil that they are *connected* by internal details (e.g. stress cables or ventilation pipes).

Invisible mechanical connections and separations

The mechanical connections and separations may become materially visible, but they consist of invisible forces and flows. Engineers draw such forces and flows in schemes with a distribution in space in order to decide how to materialise them, even though they are invisible in the final appearance. The expected stress and pressure in a reinforced concrete beam, the core of its structure, have become invisible. ‘Structural’ architects accept the laws of forces and flows and try to make them visible, as in the Eiffel Tower and many bridges. Formalists primarily design compositions to be followed by the design of an appropriate structure, as in the case of the Statue of Liberty. Gustave Eiffel designed them both.

Structure at larger scale

Could you name *variables* of structure beyond those of form? Although pressure and stress, movement and stability may be their values at the scale of a building, what is ‘structure’ in larger environments? Which values do these variables have and how could you name their third-order variables of structure?

Direction paradox of structure

Roads and dikes indicate the existence of a set of connections and separations that you can call ‘structure’ at a larger scale as well. They are usually called ‘infrastructure’. A paradox emerges, however, when studying the effect of dikes and roads in different directions. Dikes are intended to *separate* water levels, but their tops are often used as a road. This reflects a *connection perpendicular to its separation*. Roads are intended to connect, although they separate perpendicular to that direction. Planning an urban highway is intended primarily to connect parts of the city. The separation they cause between districts on both sides may be concerned as a minor ‘side effect’ of the primary connection.

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[a] Eiffel(1885)*Framework of the statue*(Scientific American)52 24
http://archive.org/search.php?query=Scientific%20American%20June%201885
Bartholdi(1883)*Album des Travaux de Construction de la Statue Colossale de la Liberte destinee au Port de New-York*(Paris), http://2.bp.blogspot.com/-zoqEQfglacY/TqsyqVDzNGI/AAAAAAAAANE/dwD0xSzaYjI/s1600/li.PNG cited in:
Levine; Story(1957)*Statue Of Liberty National Monument Liberty Island, New York*(Washington, 1957) United States Department Of The Interior National Park Service Historical Handbook Series No. 11
http://archive.org/details/statueoflibertyn00levi

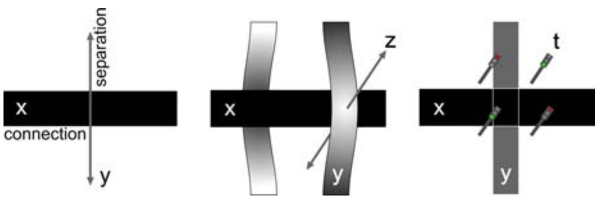

Fig. 70 Separation y ⊥ x? separate in z or t!

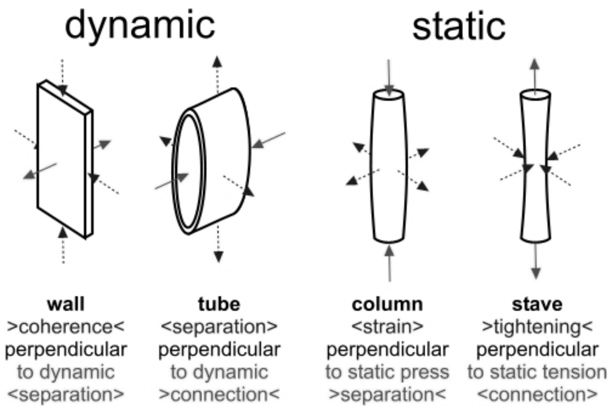

Fig. 71 Direction paradox in construction

It is a secondary problem at a smaller level of scale, to be solved next in the detailing process of design. Its solution may be to make tunnels or viaducts in order to restore some connection between the districts on both sides of the road. This is a vertical (z) separation intended to realise connections in two other directions (x and y, see *Fig. 70*). This solution, however, requires slopes on both sides, which cannot easily be crossed. These slopes cause serious separations and detours in the adjacent districts themselves. The designer can decide to separate in the fourth dimension (time) instead of the third: a crossing on the ground with traffic lights. Although this will cause delays, it will allow a periodic connection in both directions. You can observe a similar direction paradox at the scale of building construction (see *Fig. 71*):

- A wall *separates* if it is properly *connected* perpendicular to the direction of its separation.
- A tube connects only if it properly separates in the other directions.
- A column shows strain perpendicular to its separating function (enthasis).
- A stress-taking cable constricts perpendicular to its connecting function.

How could you find a one-dimensional variable for a 4D phenomenon? The direction paradox may extend beyond the directional limits of verbal expressions, logic and variables.

Verbal expressions assume one direction

The sentence ‘A road connects’ is direction sensitive. The *direction* in which it connects is a hidden assumption within the firm verbal expression. The sentence ‘A road connects and separates’ as appears to be a logical contradiction. A two-dimensional drawing allows this kind of contradictions: what is true in one direction (connection) may be false in another direction (separation). A drawing implicitly shows different directions. This assumes at least a plane. A drawing makes different inferences and conclusions possible at the same time, even if they are mutually contradictory. Verbal expressions are fundamentally one-dimensional, as is logic. A verbal, logical or mathematical inference has a strict sequence in one dimension: time. This sequence cannot always be changed without sacrificing its meaning. Its ‘side-roads’ must be neglected or distributed in footnotes, attachments, subsequent chapters or other references. Otherwise, the reader will ‘lose the way’.
Links in a website allow this kind of branched verbal communication more easily. Different readers can choose their own routes. The number of verbal routes from which to choose, however, is still more limited than in a drawing.

Weaving a picture by linear expressions is a weft without warp
A picture simulated in words must be reconstructed line-by-line, as a computer screen does with pixels. A verbal text describing an image completely with its sequences in any direction of its surface would fill many volumes with many notes, clarifying attachments or references. A drawing is easier to make and easier to understand than the verbal descriptions of many linear routes and their crossing relations. A drawing, however, allows different interpretations. At one point, a verbal description may be divided into different inferences: 'In this direction, the road connects, and in that direction, it separates'. This only multiplies the verbal effort at every point in the inference, however, and it requires many explanations of the mutual contradictions. 'To ex-plain' literally means 'to make it plane'. A picture may be worth more than a thousand words, but which words are they?

Drawings contain more directions than one line of inference
The direction of reading a drawing is not prescribed. A drawing may thus be interpreted differently by different people. That is a substantial difference between the mainly linear, possibly branched verbal language of scientists and the largely pictorial language of designers. Designers do have at least two spatial dimensions available in their drawings (apart from the time dimension). In addition, a location-bound picture does not generalise as words do. Nouns and verbs assume general concepts that are applicable in different contexts. Their hidden assumptions or generalisations are not always explicit. The pixels of a photograph do not assume anything other than a one-to-one spectral relation within an assumed reality. A legend next to a drawing is something in between; it is the vocabulary of the drawing. Nevertheless, the generalised legend units are distributed two-dimensionally in the drawing, showing at once many spatial relations in to explore in different directions.

Studying environmental structure
If you restrict your study of structure to possibilities of movement, you may find third-order variables of structure useful. By definition, movement is linear in space. It has a one-dimensional sequence that can be described in sentences, as in a travel log. For example, 'I drove in a dark tunnel, and I came out into a sunny open, flat landscape'. This sentence reveals something about the structure of the tunnel and the landscape. 'Openness' and 'seclusion' may be values to be studied at different levels of scale. Intermediate values may be found if you distinguish 'seclusion' in different directions.

Selectors
A box is closed in six directions. If you open its lid, you obtain something similar to a cup. A cup is closed in five directions. If you remove its bottom, you obtain a tube, which is still closed in four directions. A gutter, a corner and a plane are open in three, two and one direction, respectively. Moreover, you can subdivide these fundamental elements of structure by degrees of openness or seclusion. A window is open to light but closed to other movements. It 'selects' like a sieve. It is a 'selector'. Boxes, cups, tubes, gutters, corners or planes also select possibilities of movement. Any element of structure may thus be called a 'selector'. A door allows the user to select the moment of movement. It is similar to a valve.

A variable of structure

Perhaps you could identify the variable between ‘open’ and ‘closed’ as ‘selection’. Is there a zero point for this variable? Could a box be more closed than any given level of ‘seclusion’. Could you imagine an open space that is more ‘open’ than a given level of ‘openness’? An infinite vacuum may provide a zero point of selection. At the other extreme, however, even a criminal hiding in a bunker that is closed on all sides could be caught. Dictators hiding in wells or sewage tubes can be found. The degree of accessibility may thus provide infinite values of ‘seclusion’. We have thus found a variable. Perhaps there are more. Regardless of the variables that you may find for structural diversification, two environments with the same content, form and structure may still be *used* and *intended* differently. Variables of even higher order may be required to cover environmental diversification.

Searching variables of any order

The purpose of the previous exercise was merely to show the methodological possibilities and limits of a kind of study by design. There may be many more appropriate variables and kinds of study to cover environmental diversification in all of its appearances. No single study can explore all of them. However, one example of this kind of study related to empirical research and policy is sufficient to prove its possibility. It can be conducted at different levels of scale and by different orders of variables. It may be clear that different levels of scale require the selection of different variables. The different orders of variables that assume each other may be more difficult to understand (see *Fig. 72*). They condition or assume each other in an inescapable sequence for design *and* research. You cannot distinguish any intention without referring to functions. You cannot distinguish functions without making assumptions about the structure in which they perform, and the process continues.

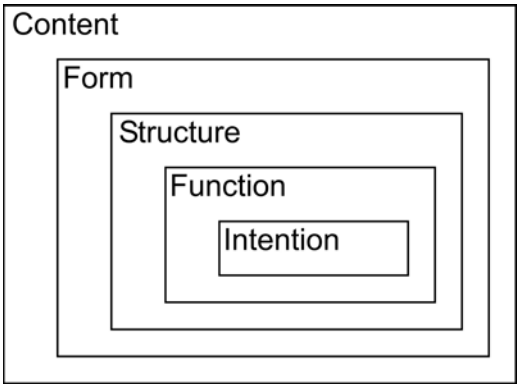

Fig. 72 Orders

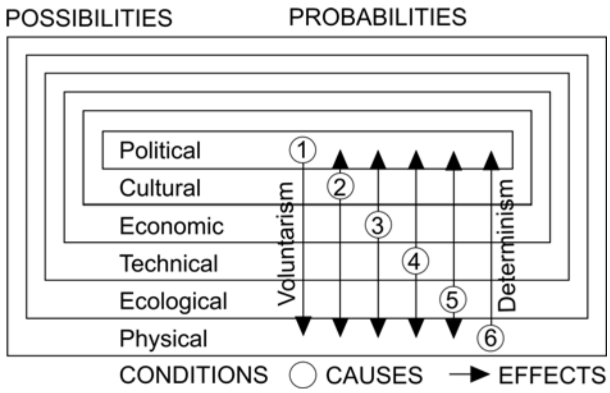

Fig. 73 Layers

There is no difference between design and research with regard to distinguishing these orders of variables. Their difference is the search for possibilities or probabilities in any order, determined by conditions or causes (see *Fig. 73*) in different layers. Empirical research is divided into science and the humanities. Science may be further divided into the specialisations of physics, biology (ecology, if the focus is on environment) and technology (or the history thereof). The humanities include specialisations with an economic, cultural or managerial focus. *Fig. 73* presents that rough subdivision, but it shows more as well. It also shows that there is a *conditional* order to these specialisations, focusing on different *layers* of the environment. In addition, there are different opinions about where causes should be found if some effect were to produce an external problem to be studied. These opinions range from voluntarism (1) into determinism (6). Although this debate has a philosophical character, a designer should be aware of its possibility.

2.8 Aims and problems expressible in words

Means-directed study

The all-encompassing objectives of the first chapter have been limited in the second. Becoming aware of the problems that a means-directed study may encounter requires an exploration of its limits. This forces the designer to address the details of these limits in advance. In doing so, the designer determines what could be studied at all. The process provides the study with an intention, a function, a structure, a form and even some content to be elaborated. It is remarkable that this kind of means-directed study apparently requires such an exercise of extending and bounding of the subject before you can properly formulate what its aims and problems actually *can* be. Part of the invention must be performed before you can do so. Only this could provide sufficient insight to formulate the aims and the field of problems listed below.

The external problem and aim

The proposed external problem is as follows: Design practice may lack instruments.
The aims of the study are therefore as follows:

1. To *find* a trans-disciplinary vocabulary by which the concept of environmental diversification can be handled and most fruitfully developed further in design, science and policy
2. To *create* a set of variables and a set of hypotheses about spatial relations suitable to elaboration and evaluation by research, and suitable to design and the realisation of any possible kinds of environmental diversification

The internal field of problems, the questions addressed

The field of problems this study may encounter can be approached by the following questions:

As a consequence of the first aim:

a. Which kinds of possible diversity can be distinguished at different levels of scale?
b. How can they be described in categories that are useful in design, science and policy?
c. What is their use for humans, society and nature?
d. How could they be developed, designed and realised?

As a consequence of the second aim:

e. Is it possible to express the categories mentioned in b as variables?
f. Are they scale sensitive and, if so, how scale sensitive are they?
g. If they are scale sensitive, how do the different levels of scale interfere?
h. Could they take on extreme values or a ‘zero’ starting point without previous values?
i. Which rationale could the sequence of their values obtain?
j. How can these values be dispersed in space beyond this sequence?
k. How do they interfere if they are not paired according to their rational sequence?
l. Are there different kinds of interference?
m. Which kinds of interference may be useful?
n. Does the diversity of opinions about this use constitute an environmental variable

3 Diversifying content

3.1 Environmental design variables

Content

Paintings with equal *colours* may still differ in the *dispersion* of their colours on the canvas. Their *relations*, *effects* or *intentions*, all suppose 'colour' as the primary set of differences. The *content* of environmental diversification, then, is any category representing possible differences in a human environment, *except and regardless* of differences of its distribution in space (form), connections and separations (structure), uses (function) and intentions. Their different dispersion, structure, function and intention are excluded because they can be *superimposed* on differences of colour, moistness, movability or another category. They are studied separately as categories of *a* different 'order' in the next chapters.

Questions to be answered

Then, the questions to be answered in *this* chapter are:

- Which spatial differences are relevant for human experience and design?
- Within which radius R={1, 3, 10…300 000m} are they relevant?
- Could they be formulated as variables with an understandable sequence of values?
- Is one of these values a fixed 'zero-point' with different distances to other values?

The way they may take form and structure, get functions or intentions, can be studied later. However, to be *possible,* these next order categories *suppose* some content. Content then should be studied first, but it is not the core of design. Designers even may 'forget' to specify the legend of their drawing. Clients then may interpret the drawing in their own way. And, that can be an advantage. It is an advantage if they exclaim 'What a nice patio!' when they are referring to a surface that was intended as a room. Forgetting a legend may unveil their tacit wishes. But, specialists evaluating a design need a legend. They may ask, 'Is this wood or steel?'. They also can say: 'This should be steel, the profile is too small for wood.' That may be an advantage that accelerates the design process. But, if you directly accept that conclusion, you may forget about the many other possibilities. And, this study is intended to discover possibilities.

No other systemization than scale

There are many environmental variables that should be distinguished, and they often overlap. I cannot avoid gaps and overlaps. If I try to avoid them by a systematic categorization beforehand, then I may tacitly reduce the possible diversity. The choice of categories that determine your variables, and their values and legend units, are fundamentally free. This chapter then offers no other systematisation than the most relevant radius of effect. You should discover other differences that are not covered in this chapter yourself. It enriches design possibilities. Try to find a sequence of values and a zero point, and name it as a variable. That may give you access to an empirical evaluation, and it may diversify the brief. The other way around, the same variable may be relevant at different levels of scale. A category covering different levels of scale may have a different meaning a different levels.

Different meanings at different levels of scale

For example, 'Light'[a] is an important variable if you read a book sitting in a chair R=1m.
It is also an important environmental variable in a room R=3m, it divides the room into different places that are suitable to watch TV, read, sleep, eat and so on.
It is important in a building R=10m to distinguish rooms with a North, South, East or West orientation. It is important for the building group R=30m with their gardens and trees to determine where you can expect sun and shadow in the course of days and seasons.
Its differentiating power may seem to fade at the larger levels of scale, but if there are hills or mountains, it may diversify their slopes until R=3km (the radius of Mt. Everest).
R=10km then seems the ultimate scale where the variable 'Light' may have an effect.
However, at R=300km it starts again distinguishing different climate zones!
At all these levels of scale the variable 'Light' may get a different meaning or effect.
They just do not have separate names. If this is the case, you may distinguish them with an index: $Light_{1m}$, $Light_{3m}$, $Light_{10m}$, $Light_{30m}$, $Light_{100m}$, $Light_{300}$, $Light_{1km}$, $Light_{3km}$, $Light_{10km}$, $Light_{300km}$. If a variable can have different meanings or impacts at different levels of scale, then it may also require the consultation of different specialists. Each of these specialists may use different parameters, a different vocabulary and method to predict the impacts of your design. Expressing 'light' then in candela, lumen or lux is not sufficient. Design is oriented on human experience. It requires more values in its legends than the scale insensitive quantitative ones.

Different disciplines at different levels of scale

If any level of scale has its own content of relevant variables, then also any level requires a different selection of specialists in your design team. The design discipline that manages their integration will be different at different levels of scale. At any level of scale, the design team must cope with different values, legend units, different possibilities to combine them and different possibilities to use ande to want them. Moreover, any *combination* of variables shapes its own conditions, which limits your freedom to disperse their values in a drawing, to give an environment form, structure and possible functions. The importance of some variables will decrease, others will increase, and new ones will emerge. The content will be different at different locations, but the possible diversity itself, the available design means, may continue to increase by design and debate. This chapter, then, may only serve as the very beginning. The treasure-chest still may be poorly filled.

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[a] The name of a variable begins with a captal in order to distinguish it from its values.

The method used to find relevant variables

The list of environmental variables in the next section was originally made through the observation of various drawings. A large collection of 10x10cm drawings and maps at the scales 1:{20, 60, 200 … 6 000 000} was used. Some of them are depicted in the next section, in order to give you an impression of the scale. For every picture, I blindly placed my fingers spaced at 5cm on its surface. Then I looked at the two environments I had hit and asked myself ‘What is the difference?’. But many other questions played a role at the same time:

What *could* be the difference?
What is in between?
Is the difference specific for this level of scale, or did I occasionally hit locations at two sides of a boundary that were conditioned by differences in a larger radius?
Are there other pairs of places with the same kind of difference?
Could I imagine larger or smaller differences of that kind?
Which extremes can I imagine then?
Is there an absolute value suitable as a zero-point?

Once Google Earth appeared, I could not stop zooming until the scale bar indicated a distance of {1, 3, 10 … 300 000m}. Then I compared places at that distance using the same method. I collected many kinds of atlases with thematic maps to study their legends and the distance between the centres of the legend units in the maps. In 1993, I received an assignment to compare the legends that were used in 28 designs that were submitted for a competition.[a] The number of legend units varied from 3 rough categories into 62 very explicit subcategories, or even objects.
If these objects are values in an imaginable range, how then would you define the variable? It is clear that you cannot avoid subjectivity in these exercises. It is not only an empirical exercise, it requires design oriented imagination. Empirical research may be the next step, using the variables to measure and to search for general relations. However, the choice of the variables precedes that research. This exercise should extend the possibilities of choice.

3.2 Variables identified

The list on the next pages (*Fig. 74*) summarises 136 variables that may be relevant for environmental diversification. It is only a selection of the variables that can vary in space and that are possibly relevant for design practice. Anyone may add other variables. The variables are not yet sufficiently elaborated to be fully operational for research and study. The selection is, however, sufficient to get an idea of the diversity of ´content´ that can be formulated as variables at any level of scale. The identified extreme values per variable are only two of the many (sometimes infinitely much) values. They may serve as legend units in a drawing. Legend units in a drawing, however, may be dispersed in a different order than the ordered values in the variable concerned. Some of the variables are elaborated in the next paragraphs as examples (indicated by ´E´ in the list). The name of a variable may be the same at different levels of scale, but its meaning and values can change. Some examples of extreme values show how their meaning may change through changes in their levels of scale. This change of meaning may be attributed to a change of resolution, but it also can indicate a substantially different meaning.

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[a] Jong;Witberg(1993) *Stromend Stadsgewest, Legenda-analyse* **IN** Klaasen;Witberg, *Het Stromende Stadsgewest derde Eo Wijers prijsvraag plananalyse* (Delft) Publicatiebureau Bouwkunde Delft http://team.bk.tudelft.nl/Publications/1993/legendaanalyse.doc

Examples 'E' elaborated on page	115	120	123	127	129	132	134	138	142	144	147	149	Examples of	0 ├──────── – – – –	
Nominal radius	**1m**	**3m**	**10m**	**30m**	**100m**	**300m**	**1km**	**3km**	**10km**	**30km**	**100km**	**300km**	Variables	Values	
General name															
Access		E	x	x	x	x	x	x	x	x	x	x	Access$_{3m}$	wall	door
			E										Access$_{10m}$	public	private
						E							Access$_{300m}$	pedestrians	cars
Agriculture								E	x	x	x	x	Agriculture$_{3km}$	fields	settlements
Allotment				x	E	x							Allotment$_{100m}$	detached	attached
Altitude				E	x	x	x	x	x	x	x	x	Altitude$_{30m}$	low rise	high rise
									E				Altitude$_{10km}$	centimetres	kilometres
											E		Altitude$_{100km}$	lowland	highland
Articulation			x	E									Articulation$_{30m}$	horizontal	vertical
Beauty	x	x	x	x	x	x							Beauty$_{1m}$	chaotic |boring	recognition |surprise
Backing		E	x	x									Backing$_{3m}$	corner	centre
Boundary Richness		x	E	x	x	x	x	x	x	x	x	x	B. Richness$_{10m}$	sharp	vague
Building Shape				x	x								Building Shape$_{30m}$	accumulated	dispersed
Building Size						E							Building Size$_{300m}$	small	large
Cables And Pipes			x	x	x	x	x	x	x	x	x	x	Cables And Pipes	matter	information
Catchment Area												E	Catchment Area$_{300}$	mountainous	delta
Centrality						E	x	x	x	x	x	x	Centrality$_{300m}$	centre	periphery
Change	x	x	x	x	x	x	x	x	x	x	x	x	Change$_{1m}$	seconds	millennia
Character	x	x	x	x	x	x	x	x					Character$_{1m}$	introvert	extrovert
Climate			E	x							x	x	Climate$_{10m}$	stable	variable
												E	Climate$_{300km}$	cold	warm
Colour	E	x	x	x									Colour$_{1m}$	black	white
Connection	x	x	x	x	x	x	x	x	x	x	x	x	Connection	1m	10 000km
Control			E	x									Control$_{10m}$	uncontrollable	controllable
Consumption	x	x	x	x	x	x	x	x	x	x	x	x	Consumption$_{1m}$	0	1Mg/m^3*sec
Coverage		x	x	E									Coverage$_{30m}$	sky	roof
Culture	x	x	x	x	x	x	x	E	x	x	x	x	Culture$_{3km}$	traditional	experimental
Curvature			x	x	x	x							Curvature$_{100m}$	straight	curved
Deliveries			x	x	x	x	x	x	E	x	x	x	Deliveries$_{10km}$	contribution	distribution
Demography									E	x	x	x	Demography$_{10km}$	homogeneous	heterogeneous
Density						E	x	x	x	x	x	x	Density$_{300m}$	vacant	built
Detailing	x	x	x	x	x	x	x	x					Detailing$_{1m}$	characteristic…	… marking
Difference	x	x	x	x	x	x	x	x	x	x	x	x	Difference$_{1m}$	equality	difference
Directions			x	x	x	x	x	x	x	x			Directions$_{10m}$	one	many
Dwelling Seclusion			x	x									D. Seclusion$_{10m}$	front	back
Dynamics			x	x	E	x	x	x	x	x	x	x	Dynamics$_{10m}$	sleeping room	workspace
							x						Dynamics$_{1km}$	quiet	busy
Ecology			x	x	x	x	x	x	x	x	x	x	Ecology$_{10m}$	homogeneous	heterogeneous
								E					Ecology$_{3km}$	lifeless	many species
Ecological Rareness		x	x	x	x	x	x	x	x	x	x		Ecological Rareness	1m	10 000km
~ Replaceability		x	x	x	x	x	x	x	x	x	x		Replaceability	1yr	1 000 000yr
Economy						x	x	E	x	x	x	x	Economy$_{3km}$	consumption	production
Economic Capital							x	x	x	x	x	x	Economic Capital$_{1km}$	0	$1\text{billion\$/km}^2$
~ Employment					x	x	x	x	x	x	x	E	Employment$_{300km}$	0%	100%
~ GDP										x	x	x	Gdp$_{1km}$	0	15 000billion$
~ Income					x	x	x	x	x	x			Income$_{100m}$	low	high
~ Power							x	x	x	x	x	E	Power$_{1km}$	dominant	serving
~ Sector							x	x	x	x	x	x	Sector$_{1km}$	primary	tertiary
Elevation			x	x	x								Elevation	flat	mountainous
Energy Conversion	x	x	x	x	x	x	x	x	x	x			Energy Conversion$_{1m}$	0	100kW/m^2
Expression	x	x	x	x	x								Expression$_{1m}$	inexpressible	expressible
Filling			x	x	E	x							Filling$_{100m}$	space	mass
Form	x	x	x	x	x	x	x	x	x	x	x	x	Form$_{1m}$	accumulation	dispersion
Formality				E	x	x							Formality$_{30m}$	street	backyard
Freedom Of Movement		E	x	x	x	x	x	x					Freedom O.M.$_{3m}$	stay	run

Examples 'E' elaborated on page	115	120	123	127	129	132	134	138	142	144	147	149	Examples of	0	———— – – – –
Nominal radius	**1m**	**3m**	**10m**	**30m**	**100m**	**300m**	**1km**	**3km**	**10km**	**30km**	**100km**	**300km**	Variables	Values	
General name															
Floor/Space (Fsi)					x	x	x	x	x				Floor/Space	0%	100 000%
Formality		x	x	x	x	x							Formality$_{3m}$	informal	formal
Function	x	x	x	x	x	x	x	x	x	x	x	x	Function	multi-functional	mono-functional
Furniture		E	x	x									Furniture$_{3m}$	bed	cupboard
Geology									E	x	x	x	Geology$_{10km}$	years	millennia
Geomorphology										E	x	x	Geomorphology$_{30kmM}$	erosion	sedimentation
History							E	x	x	x	x	x	History$_{1km}$	-300 million yr	10 yr
Housing			x	x	x	x	x	E	x	x			Housing$_{3km}$	single	family
Hygiene	x	x	x	x	x	x	x	x	x	x	x	x	Hygiene$_{1m}$	clean	contaminated
Identity	x	x	x	x	x	x	x	x	x	x	x	x	Identity$_{1m}$	equal|changing	different|stable
Identification Value	x	x	x	x	x	x	x	x	x	x	x	x	I. Value$_{1km}$	nondescript	striking
Image							E	x	x				Image$_{1km}$	homogeneous	heterogeneous
Imaginability	x	x	x	x	x	x	x	x	x	x	x	x	Imaginability$_{1m}$	inconceivable	conceivable
Influence	x	x	x	x	x	x	x	x	x	x	x	x	Influence	1m	10 000km
Involvement	x	x	x	x	x	x	x	x	x	x	x	x	Involvement	1m	10 000km
Information	E	x	x	x	x	x	x	x	x				Information$_{1m}$	poor	rich
			E										Information$_{10m}$	boring	chaos
Intensity							E	x	x	x	x	x	Intensity$_{1km}$	0hrs/yr	8760hrs/inh.*yr
Intention	x	x	x	x	x	x	x	x	x	x	x	x	Intention$_{1m}$	plan	desires
Landscapes									E	x	x	x	Landscapes$_{10km}$	natural	urban
Land Use									E	x	x	x	Land Use$_{10km}$	0	many hr/m^{2}yr
Legislation												E	Legislation$_{300km}$	free	strict
Life	E	x	x	x									Life$_{1m}$	a-biotic	biotic
Life Style					x	x	x	x	x	x	x	x	Life Style	consumer	careerist
Light	E	x	x	x								x	Light$_{1m}$	dark	light
		E											Light$_{3m}$	sun	shadow
Lineage					E	x	x	x	x				Lineage$_{100m}$	directed	undirected
Logistics						x	x	x	x	x	x	x	Logistics$_{300m}$	contribution	distribution
Management	x	x	x	x	x	x	x	E	x	x	x	x	Management$_{3km}$	laissez-faire	initiative
Market						x	x	x	x	x	E	x	Market$_{100km}$	local	international
Material	E	x	x	x									Material$_{1m}$	stone	organic
		E											Material$_{3m}$	air	solid
Meeting								E	x				Meeting$_{3km}$	home	work
Migration					x	x	x	x	x	x	x	x	Migration	0	high
Moistness		E	x	x									Moistness$_{3m}$	dry	wet
Movability	E	x	x	x									Movability$_{1m}$	fixed	moveable
Nature										E	x	x	Nature$_{30km}$	dry	wet
Nature Preservation			x	x	x	x	x	x	x	x	x	x	N. Preservation	isolation	connection
Network Density							E	x	x	x	x	x	Network Density$_{1km}$	0.7km/km^2	7km/km^2
Networks										E	x	x	Networks$_{30km}$	isolation	access
Noise				E	x	x	x	x	x				Noise$_{30m}$	silent	noisy
Occupation							E	x	x	x	x	x	Occupation$_{1km}$	natural	urban
Order	x	x	x	x	x	x	x	x	x	x			Order	content	intention
Orientation			E	x									Orientation$_{10m}$	undirected	directed
Organisation	x	x	x	x	x	x	x	x	x	x	x	x	Organisation$_{1m}$	anarchy	regulated
Overview		x	x	x	x	x	x	x					Overview$_{100m}$	closed	open
Parking				x	x	x	x						Parking$_{30m}$	0	5 parkingplaces/inh.
Passability			x	x	x	x							Passability$_{300m}$	unpaved	paved
Pattern			x	x	x	E	x	x	x	x	x	x	Pattern$_{300m}$	repetition	variation
Plantation				E	x	x	x	x	x				Plantation$_{30m}$	paved	green
Polarity	x	x	x	x	x	x	x	x	x	x	x	x	Polarity$_{1m}$	many sided	one-sided
Pollution							E	x	x	x	x	x	Pollution$_{1km}$	clean	contaminated
Population Density			x	x	x	x	x	x	x	x	x	x	P. Density$_{10m}$	0	100 000 inh./km^2
Population Growth							x	x	x	x	x	x	P. Growth$_{1km}$	0	10%/yr
Population Age		x	x	x	x	x	x	x	x	x	x	x	Population Age$_{3m}$	children	adults

Examples 'E' elaborated on page	115	120	123	127	129	132	134	138	142	144	147	149	Examples of	0	
Nominal radius / General name	**1m**	**3m**	**10m**	**30m**	**100m**	**300m**	**1km**	**3km**	**10km**	**30km**	**100km**	**300km**	Variables	Values	
							x						Population Age$_{1km}$	starters	elderly
Public Transport						x	x	x	x	x	x	x	Public Transport$_{300m}$	10km/hr	1000km/hr
Precipitation			x	x	x	x	x	x	x	x	x	x	Precipitation$_{10m}$	0	200mm/hr
Production	x	x	x	x	x	x	x	x	x	x	x	x	Production$_{1m}$	0	1000kg/m^3*sec
Reach	E												Reach$_{1m}$	within	outside
Regulation			E	x									Regulation$_{10m}$	wasteland	property
Relief					E	x							Relief$_{100m}$	flat	steep
Resources											E	x	Resources$_{100km}$	internal	external
Risks										E	x	x	Risks$_{30km}$	nuisance	floods
Road Width						x	x	x	x	x	x		Road Width$_{300m}$	3m	100m
Routing						x	E	x	x				Routing$_{1km}$	points	surfaces
Selection	x	x	x	x									Selection$_{1m}$	non-selective	selecting
Separation	x	x	x	x	x	x	x	x	x	x	x	x	Separation$_{1m}$	open	closed
Size	E	x	x	x	x	x							Size$_{1m}$	large	small
Soil						E	x	x	x	x	x	x	Soil$_{300m}$	rock	water
											E		Soil$_{100km}$	clay	rock
Specialisation	x	x	x	x	x	x	x	x	x	x	x	x	Specialisation$_{1m}$	1m	10 000km
State Of Matter	E	x	x	x									State Of Matter$_{1m}$	solid	gas
Status					E	x	x	x	x	x	x	x	Status$_{100m}$	poor	rich
Street Furniture				E									Street Furniture$_{30m}$	kerb	lamppost
Structure	x	x	x	x	x	x	x	x	x	x	x	x	Structure$_{1m}$	connection	separation
Sun		x	x	x	x							x	Sun$_{3m}$	sunlight	shadow
				E									Sun$_{30m}$	morning	evening
Surface	E	x	x										Surface$_{1m}$	hard	soft
Task Division											E	x	Task Division$_{100km}$	agriculture	services
Technology	x	x	x	x	x	x	x	x	x	x	x	x	Technology$_{1m}$	combination	separation
								E					Technology$_{3km}$	energy	information
											E		Technology$_{100km}$	drainage	irrigation
Temperature	E	x	x	x									Temperature$_{1m}$	cold	hot
		E											Temperature$_{3m}$	cool	warm
Territorality			E	x	x								Territorality$_{10m}$	public	private
Time Use	x	x	x	x	x								Time Use	0	8 760hr/yr
Traffic					x	x	x	x	x	x	x	x	Traffic$_{3km}$	local	trough traffic
Transfer										E	x	x	Transfer$_{30km}$	walk	fly
Vegetation				x	x	x	x	x	x	x	E	x	Vegetation$_{100km}$	wet	dry
View		E	x	x	x	x	x	x					View$_{3m}$	wall	window
Visibility		E	x	x	x	x	x	x					Visibility$_{3m}$	invisible	visible
Water				E	x	x	x	x	x	x	x	x	Water$_{30m}$	land	water
Water Storage									E	x	x	x	Water Storage$_{10km}$	0	1 500km^3/day
Waterways										E	x	x	Waterways$_{30km}$	natural	artificial
Wind			x	x	x	x	x	x	x	x			Wind$_{10m}$	directed	turbulence
Zoning						E	x	x	x				Zoning$_{300m}$	natural	artificial
…															

Fig. 74 Variables relevant for design

3.3 Design variables R=1m (0.3 - 3m)

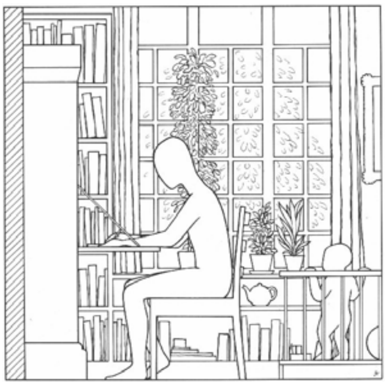

Fig. 75 Example 2x2m[a]

	0	
Light$_{1m}$	dark	light
Colour$_{1m}$	black	white
Temperature$_{1m}$	cold	hot
State Of Matter$_{1m}$	solid	gas
Surface$_{1m}$	hard	soft
Material$_{1m}$	stone	organic
Size$_{1m}$	large	small
Movability$_{1m}$	fixed	moveable
Reach$_{1m}$	within	outside
Life$_{1m}$	a-biotic	biotic
Information$_{1m}$	poor	rich

This list of possible design variables R=1m is not complete. The values mentioned are supposed to be extremes, with many in between values. Most of them do not have a proper name. One of the extremes is supposed to be an absolute value (zero-point), from which the other values are a specific distance away from. The names of the extremes are the best I could find, and perhaps they are still not the most appropriate.

Light$_{1m}$

Differences of ‘Light’, as they appear in a radius R=1m (0,3m - 3m), diversify environments in nature, in public spaces, gardens and interiors within arm’s reach. The sources of light are sky phenomena, such as the sun or fire, lamps and electronic screens. The framing of light by windows, the character of the sources, their locations and those of the nearby objects that are illuminated with more or less reflection, may all play a role in your design. If you design the local diversity of light only by locating its absolute values expressed in lumens or lux, then that ‘required’ quantity is a small part of the design variable. It ranges from ‘dark’ to ‘light’, with the infinite and changing values in between you may experience.

More than a quantity of light

The accommodation of your eyes makes relative differences between these values more decisive than the measured or prescribed absolute ones. The proportional contribution of different sources may change if a cloud darkens the sun or if the evening falls and you put the lights on. The differences between direct, filtered and diffuse light caused by refraction, reflection and shadows, the colour of the source, and its eventual dynamics compared to what you remember, may generate a complex and often unexpected environmental diversification in your playpen, on your desk, or outdoors. In the open air, the changes during days and seasons, amongst other changes, determines the natural selection of plant species. A growing tree will change the scene through the seasons and the years. If the outside world is covered with snow, then your room will look different. The reflected white light from below, entering upwards through your window, reflected by the ceiling downward, changes everything.

Infinite qualities between darkness and light

You may categorize the design variables in many other measures, but their unpredictable and changing combinations are, in the end, what defines your design. It belongs to the portfolio and repertoire of architects as ‘light-artists’. To determine the intermediate values you should make your own palette of light-forms, based on your own experience. Once you

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[a] Huffener(1977) drawings in: Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis

find a remarkable kind of light somewhere, make a sketch from the sources and nearby reflective objects. If you apply them in your design, then they will not have the desired effect all the time. However, even if the desired effect only occurs sometimes, it is fixed in the memory of the users, or by a photograph, as a particular historical quality of the place. In a museum, a laboratory or an office you may try to make it permanent, but change may be a quality in and of itself.

Compositions, structures and functions of light values

The same local content, e.g. the values you chose from that design variable $Light_{1m}$, still may be differently *distributed* in space, but this will not to be discussed further. The same value may be scattered throughout the view, or it may be concentrated at one spot by a beam shaping different compositions of light. Different adjacent values at your desk may then contrast each other through their sharp boundaries, or they may shade into each other, structured by their sources and the 3D illuminated surface. These alternatives of light-form and -structure subsequently may or may not be useful for different functions. They also may or may not be intended.

Orders of diversity

However, these values of form, structure, function, and intention are superimposed on the dark-light content itself, as second-, third-, fourth- and even fifth-order design-variables. They diversify your environment again, but in a different way. Since these higher-order variables can be applied at any content, they will be discussed in the next chapters. However, it is not always easy to separate content from form, structure and function. They can all be used as legends for design, as contents with a distribution in space. What you can call ‘content’ at one level of scale may appear as form at another level. Even light can be described as waves, as different sinus-forms at the nanometer scale. That is why the content and its variables should at least be bound to scale.

$Colour_{1m}$

Colour supposes light. It is the selective reflection of light by surfaces in the direction of your eyes, but you experience it as a characteristic of that surface itself. It is the most important and fastest way to distinguish surfaces from each other. In the dark, you need other senses such as touch, to do so. If anything in the environment would have the same colour, then you could not see anything. Vision supposes *differences* of colour. Without these differences, at R=1m you would not be able to read, to distinguish objects, to take them if you need them, or to avoid bumping into them. Different people may experience colour differently, but even colour-blind people see differences. Touch, taste, smell and even hearing may help the blind, and they inform you of depth. Synaesthetic people connect impressions of other senses directly to colour. Categories of colour then may exist in your mind and your vocabulary separately from their external existence. And these categories depend on your cultural background. They can get shared associations as ‘red’-‘danger’ or ‘green’-‘safe’ as used in traffic lights.

Levels of diversity

A single colour can be measured by instruments as the frequency f or the wavelength λ, connected by the constant velocity of light $c = \lambda f$.
But for humans, colour is scale sensitive. Seen at some distance, a mixture of colours may produce a different ‘colour’. This implies that for designers, $colour_{1m}$ is different from $Colour_{3m}$. It is also influenced by the differences between $light_{1m}$ and $light_{3m}$, since colour supposes light. For a child’s book or room, a reduced palette of primary colours, sharply separating the objects, is popular and supposed to be instructive. However, gradual transitions and less contrasting elements in the evening may cause less arousal.

Composition beyond content
Designing as 'giving form to material' makes colour differences less popular in 3D architecture and sculpture than in 2D painting, since they emphasise the form. Colour is sometimes used to distinguish repetitive forms, such as the storeys of a gallery flat, in order to mask 'poor design'. The use of colour in this manner may improve the perceived quality of a poor design. It then may strengthen the impression of poor design if you apparently have to use colour to get identity. However, potential clients with a different aesthetic taste may be put off by the design. Colour can stress details as points of orientation, or indicate functions, such as entrances, public post boxes or policemen. Darker window frames may suggest shadow and depth, developing a sculptural effect when one views the façade. Since R=1m, 3D furniture and cars appear in many colours. The whish to use colour differences may be scale sensitive. There are a few examples of towns or villages in one particular colour (e.g. 'white villages' as Thorn in the Netherlands or blue-and-white villages in Greek holidays travel advertisements representing the colours of the Greek flag).

Temperature$_{1m}$
At R=1m, the temperature of objects may be more relevant than air temperature. Air temperature differences become more important at other levels of scale. Even temperature then is scale sensitive. You may doubt if temperature is a R=1m design variable at all, but it is worth the effort to explore its possibilities. If you have been in a space without floor heating, you may have experienced a warm head and cold feet at your desk, table or in a chair. In natural environments, R=1m temperature differences definitely play a role, causing different plants and insects to be located in different areas. But for indoor plants must endure the dynamics between cold windows providing light and heating elements below. Cold downward flows from the windows intersect the warm upward flows in an unpredictable turbulence. Cold flows mainly descending to the floor may be relevant for young children, old and sick people. I once asked a 3 year old girl "What is a mother?". She answered "Big and warm". Could you invent more 'big and warm' objects or surfaces? To *avoid* contact with the hot surfaces of a furnace or heating elements may be a concern of R=1m design anyhow.

State Of Matter$_{1m}$
The boundary between land and water is favoured by people to stay, yet many waterfronts are designed as sharp boundaries, steep quays or even as dangerous fenced places. In natural environments, less steep banks provide many alternatives between wet and dry for their flora and fauna. But you do not have them in your bathroom, your kitchen or even in your garden. You probably do not enjoy rain as much as people from dry climates. On rainy days, the wet outdoor environment and your dry room is strictly separated by walls and windows, with a transition boundary of only a few centimetres. Could you design more extended and accessible values in between? Many people like an aquarium, a little pond or a moisty indoor sunroom. Children like to play with clay, sand, and water.
Ventilation systems remove gases such as CO_2 to provide O_2, but odours and smells from kitchens, churches, laboratories, people and flowers may remain unconsciously in your memory as a 'sense of place'. They are seldom an object of design. However, perfumes are designed and their formulae are kept secret. Aerosols such as smoke may be attractive or repulsive, but either way, they diversify environments. Smell is added to cooking gas as a warning, but smoke generators create a mysterious, misty atmosphere around performances or in discos, in an attempt to unchain the power of your imagination.

Surface$_{1m}$

You need a hard, flat surface to write, but a soft, curved one to sit at your desk. The difference between hard and soft surfaces is immediately understood as locations for movement and rest. In natural soils and vegetation, the surface differences of objects alternate at many levels of scale. But in artificial environments, soft surfaces are mainly used as smaller indoor additions, such as curtains, carpets, pillows, or soft furnishings. Softness can change the surface of a form, such as the adaptation of the human body by clothes. The skin of humans is soft and curved, but their artefacts are mainly hard and straight. However, industrial designer increasingly add soft and curved surfaces to ballpoints, tooth brushes and cars. Architecture increasingly allows curved surfaces, but its materials remain rigid and hard, in order to resist movement. But, moving your legs under a table, you have to take care of your knees.

Material$_{1m}$

Buildings, walls, columns, ceilings and roofs should be stable, strong and rigid, as you can learn in building structures lessons. These primary requirements of building construction are mainly fulfilled through the use of common building materials, such as concrete, steel, brickwork and wood. But at a smaller scale than buildings, these materials are often finished by plasterwork, paint or wallpaper, hiding their inner nature. The walls of buildings are interrupted by doors and windows made of wood, plastics and glass. Their rooms are filled with even more materials chosen by other manufacturing and use requirements. However, you will still find the greatest diversity of materials in nature. Organic matter consists of an inconceivable amount of chemical compounds, differentiating the natural environment at many levels of scale. They do not only serve stability and strength, but also growth, recycling and reproduction. But, they seldom serve rigidity. Organic material is more flexible, and less rigid than building materials. Will these numerous possibilities between stone and organic material remain irrelevant for future buildings?

Size$_{1m}$

Size is obviously a design variable, but it contains more than the square metres of your brief and the millimetres measured out in order to detail your drawings. It is also spatial variable diversifying your environment at different levels of scale. The objects that surround you, differ in size. At home you may be surrounded by small-sized objects and outside by large-sized objects, but this difference already plays a role within a radius of R=1m. You can express any size in metres, but your concept of size starts with the *difference* of sizes, and their proportions. Your experience of size changes by distance and age. As a child, everything was bigger for you. Your playpen was your room. If something frightened you, then you could run away to make it smaller. If it was small enough, then you could safely turn around to have a look, in order to put it in perspective with what you already knew. Your parents may have given you small models to understand the large objects they represent (e.g. dolls, toy cars, building blocks). You got a teddy bear, figurative toys, dangerous looking transformers to overcome your fear of what you may have seen or dreamed but never 'really' touched R=1m. By holding them in your hands, they became less threatening. You could manipulate them, throw them away to decrease their size, and learn that it was still the same object, be it out of reach, out of your playpen, or out of the box. You have learned that the face of your mother filling your scope while she took you up in her arms was the same as the small figure appearing at the door. You learned to call her when she was out of reach and sight. Sitting at your desk, you may have kept the smaller objects, such as ballpoint pens and paper, close by, and the larger objects, such as your dictionary, printer and storage boxes, further away. You may have done it in the kitchen too.

Movability$_{1m}$

Left and right in *Fig. 75* on page 115, ‘wall’ and ‘ball’ represent extremes of movability$_{1m}$. In between values may be recognized in cupboards, chairs and books. From any move into another home or rearrangement of your room, you may have experienced the importance of the objects’ movability strongly related to their size and weight. But, movability is more than size and weight. ‘Movability’ is a separate design variable$_{1m}$, because design can separate it from size and weight, by applying a wheel, a hinge or curtain rails. Manipulating objects, pushing a carriage and learning to cycle have played an important role in the development of children. Since Piaget demonstrated the importance of the motor senses for learning, early education and school interiors have changed. Gymnastics and sports were recognised as more important for the development of orientation and coordination abilities than previously thought. How to get an optimum between fixed and moveable by R=1m design? That optimum may be different in an office compared to a living room. But sitting for hours in an office may raise a demand to make chairs less rigid. Movability may be a design variable that is relevant in nearly any environment. Even walls and floors can be made moveable, which is often done in conference environments and air cushion playground equipment. But, if you make everything moveable, then the user may become disoriented or lose control of their coordination. Movability can be restricted to translation or rotation, which can be found in doors, windows or even rotating shelves in corner cupboards.

Reach$_{1m}$

Within a radius R=1m, not everything is always immediately accessible or within reach. Constructive parts may be out of immediate reach or sight, parts may be locked with a key or out of reach for the physically disabled. Reach is an ergonomic design variable, which is important in kitchens, desks or other workplaces that are intended to serve repetitive actions and for disabled people. The reach of pathogens, is also a variable of hygienic design.

Life$_{1m}$

Many of the above mentioned variables such as Light, Temperature and State of matter, influence the emergence and survival of living organisms, whether it is desired or not. But, their actual presence can be a design variable itself. It determines the environmental diversity of the natural environment at any level of scale, of public spaces, gardens and indoor spaces. People love and fear life. Within their houses they may keep plants and animals to differentiate their direct environment. Other strategies include fish bowls, birdcages or houseplants on their windowsill, table or desk. But they avoid vermin. Within a R=1m radius, the range between dead and living matter may contain memories or associations. A wooden tabletop is easier accepted than a concrete one. Fossils in natural stone may be appreciated. Climbing vegetation on exterior walls and fences are often welcomed. How to enrich the mainly dead human environments with living content?

Information$_{1m}$

The information content of an environment approaches its diversity in the following manner. For human appreciation, it should not exceed the borders into too little or too much, boredom or chaos. Between these limits it should enable recognition and surprise. Information comes down to the diversity that can be recognized and understood. It is enabled and conditioned by culture, age and employment. Busy managers may need a clean desk to compensate for their hectic day, but quiet scientists or artists, able to cope with much information amid diverse information categories, may have a messy desk. Information is scale sensitive. One level of scale may compensate the other. An information content R={1, 10, 100m} may be high if it is low at R={3, 30, 300m}, or the reverse.

3.4 Design variables R=3m (1 - 10m)

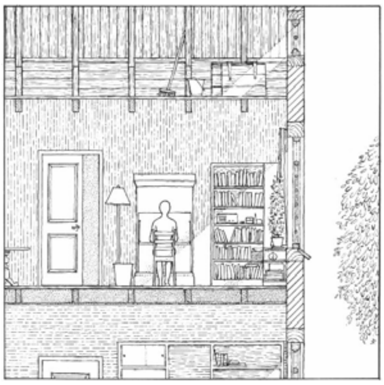

Fig. 76 Example 6x6m[a]

	0	
View$_{3m}$	wall	window
Light$_{3m}$	sun	shadow
Visibility$_{3m}$	invisible	visible
Temperature$_{3m}$	cool	warm
Moistness$_{3m}$	dry	wet
Material$_{3m}$	air	solid
Backing$_{3m}$	corner	centre
Freedom of movement$_{3m}$	stay	run
Furniture$_{3m}$	bed	cupboard
Access$_{3m}$	walls	door

The variables Colour$_{1m}$, State Of Matter$_{1m}$, Size$_{1m}$, Movability$_{1m,}$ Life$_{1m}$, Information$_{1m}$ are already named in 3.2. But, in a radius of R=3m, e.g. a room, they produce a different kind of environmental diversity than they did in a radius R=1m. Their values changed. The variables may have changed also. If they do not have a different name at this scale, then they still have a different index.
For example, Temperature$_{1m}$(cold-hot) is intended to be related to solid objects. That is something else than Temperature$_{3m}$(cool-warm) , which is intended to be related to air temperature. The environmental characteristics experienced walking 3m are different from those sitting at your table with a personal reach of 1m. There may be a diverse array of disciplines involved, from industrial design and ergonomics into interior design. But, it is not always as easy as talking about temperature.
For example, instead of Light$_{1m}$(dark-light) I arbitrarily chose Light$_{3m}$(shadow-sun), but I am still not convinced if that exactly covers your experience at R=3m. The same *variable* name in radii R=1m and R=3m may cover two fundamentally different sets of *values*.
To describe the differences in a radius of R=3, you also need *new* variables. I will explore some earlier named variables again to show the difference, but then I will only elaborate on the additions in the list below. That list is certainly not complete. You should always keep looking for your own legend units. In trying to name units as particular values from a range of possible values I still did not name as a variable here and in the lists of additions to follow at the next levels of scale.

View$_{3m}$

Take off your spectacles, stand up, stretch your legs and look around. Your desk with papers, your ballpoint and your emptied coffee cup becomes one of the scenes between the others. You look at a picture at the wall, you see your child playing, and you walk into the window where the sun shines on the floor, on some books in your bookcase and on your plants at the windowsill. You feel a draught of cold air. Through the window you see the tree in front of your house waving in the wind, the houses at the opposite side, and looking down you see people walking and cars driving. Looking back into your room, you see the furniture fading against a darker background. The diversity of views that you experience between the desk and the window vary according to the design variables that are present in your room. You saw their values of light, colour, size, material and so on appear and disappear in different sequences, as views. They appeared at a larger scale when you were at the window, than when you were sitting at your desk, with different contents. And, there are still other design variables than those represented in the views. They may appear by movement,

[a] Huffener(1977) in: Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis

repair activities or (unconscious) use. And, any chair has its view. Did you realize that when you were putting them in their place in the room? What did your visitors see talking to you? It is amazing to study the location and orientation of banks in a park. How often the designers force you to look at asphalt with a beautiful landscape right behind you.

Light$_{3m}$

The size, position and orientation of your windows condition the potential access of daylight. Its effect changes at the surfaces it hits. Parts of its spectrum are reflected or diffused, fading with the distance to the windows, eventually mixing with other sources of light. They will replace daylight in the evening or during the day, if you turn on the lights and close the curtains. Different windows and other light sources receive a different combined effect at any location in the room. The produced differences *between* R=1m light sources experienced in a radius R=3m is something else than the diversity *within* each R=1m light source. You might name them as differences between ‘desk light’, ‘table light’, ‘chair light’, ‘kitchen light’ and so on. But that still will not cover the possible shades averaged for every R=1m light source in a radius of R=3m. They simply do not have a name. Painters may suggest some of them in their paintings with clair-obscur and sfumato, but how to cope with them in spatial design?

Visibility$_{3m}$

In your room, not everything is visible. But invisible objects and areas may still be essential for use. Many utensils are hidden in drawers or behind cupboard doors, to hide a mess. This chaotic view causes you to lose time when you are looking for something. The construction and material of the floor, the walls, windows and doors are hidden behind a layer of plaster, paint, carpets or curtains. The ventilation, electricity, sewage and water supply systems, and their cables and pipes, are hidden in the construction. But, you need them and you eventually have to uncover them when system repairs become necessary. That is not only the case in your room, but also in your garden, public spaces and even in nature. Under your feet, there is still an invisible world that is essential for the visible world. But still, designers make a sharp division between the visible and invisible. And that is not always necessary. In a school of architecture, you can omit the ceiling that covers the cables and pipes. It is cheaper and easier to maintain, and it may serve an educational purpose. The visual effect is not disturbing in that context, and it can even provide an improvement to the typical room, if the ceiling is higher than normal.

Temperature$_{3m}$, Moistness$_{3m}$, Material$_{3m}$

Within an action space R=1m, the object temperature may be relevant to avoid burns or cold limbs, but the air temperature in that radius is more mixed into an average. Within a radius of R=3m (ranging form 1 to 10m), the air temperature becomes more important. But, it will reach its peak at R=10m, where the boundaries between indoor and outdoor spaces are drawn. Temperature is often related to moistness. Cold surfaces attract moisture. But that is not always the case in kitchens and bathrooms where even warm surfaces may become wet. Moistness, then, is a separate design variable that requires a different surface material at areas where you may expect moisture and water. The diversity of materials in your environment is probably greatest in your living room. There may be a difference of material between the wall, the floor and the furniture. Coatings, sheeting, and curtains may differ. These values are different from the materials that diversity an environment R=1m (see page 118). There I chose values based on their inner properties of construction and production. Here I would make choices based on the more visual values of their surfaces, with the zero-point being ‘air’.

Backing$_{3m}$, Freedom Of Movement$_{3m}$, Furniture$_{3m}$

In the corner of a room, your freedom of movement is restricted by the walls that meet in an angle. The spatial corner affects the possibilities for using the space, and the location of the furniture. If you place a square table surrounded by chairs in a square corner, then people in the corner will have problems passing by the other chairs. This problem can be solved by choosing a triangular table, as I once did. If you cover the corner with a cupboard, then you cannot access the spaces in the corner itself, except if the cabinet has rotating round shelves, as I constructed once. If you put your bed there, then it becomes difficult to make the bed in the morning. If you put a chair or playpen there, then you get a quiet place with a solid background, or shelter. But, it is not a place to run or play around, since you will bump against the walls. The centre of the room is better suited for such activities. You could call the design variable involved ‘backing’. It appears in any bounded area, and it is related to freedom of movement and the kind of furniture that is in the area. However, detailed designing may eliminate these relationships, as I mentioned above. That is why they are still presented as separate variables.

Access$_{3m}$

Access will also play an essential role in the larger radiuses. But, within a radius R=3m, doors already have an access-effect, different from that of R=3km roads. Any room has at least one door, and a zoning around that door that ends at the corners of the room, where mobility and movability are lowest. However, the *access* design variable is related to structural questions of connection and separation that *allow* more or less access. Connections and separations are the subject of chapter 5 on structural diversification, a variable of a higher order that can be superimposed on any of the previous variables. Windows and doors give more or less access to a room or a building. That connecting property is not the same as the properties of materials within the structure of walls, windows and doors connecting perpendicular to their performance of giving access.

3.5 Design variables R=10m (3 - 30m)

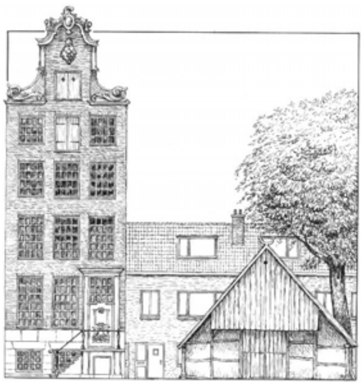

Fig. 77 Example 20x20m[a]

	0	
Access$_{10m}$	accessible	inaccessible
Orientation$_{10m}$	undirected	directed
Climate$_{10m}$	stable	variable
Boundary Richness$_{10m}$	sharp	vague
Information$_{10m}$	boring	chaos
Territorality$_{10m}$	public	private
Regulation$_{10m}$	wasteland	property
Control$_{10m}$	uncontrollable	controllable

Access$_{10m}$

A counter-intuitive zero-point

Access to your garden, your house or its attic may be enabled by connections, such as paths, passages, and staircases, or it may be hindered by separations such as fences, walls, doors and windows. But, as a primary design variable, motoric or sensoric access for people is not the same as the connections and separations they meet. Access is more related to the time and effort they have to spend. Any place within a radius of R=10m is accessible, but climbing a tree to reach its summit will take more time and effort than climbing the staircases into your attic. Total accessibility then is (somewhat counter-intuitive) a zero-point. It is anything within your Reach$_{1m}$ from the area you are in. If you would look for a numerical measurement of Access$_{10m}$, then you should add up all the time and efforts you need to reach every other area within a radius of R=10m. Since that calculation would include calculating the time and effort to reach every other area separately, such an attempt is only useful as a thought experiment. This calculation allows you to make a rough estimation of access, for example, to roughly determine your intuitive awareness of access and reach from the toilet to your children that are playing outside.

Access to and from a building

Anyhow, any area then *has* its own value of (outward) access$_{10m}$ to all the other areas within that radius. It is counter-intuitive, because a *higher* access-value indicates a *less* accessible environment. You can always add more barriers. You may suppose that areas inside buildings have a higher access-value than areas in the open air with its freedom of movement$_{3m}$, because a building usually has more separated spaces that must be passed through to get from one side to the other. But, if you do not have a key, then entering a house takes more time and effort than going out. If children go out to play (increasing their freedom of movement$_{3m}$), then the buildings around them are inaccessible, except if they have their keys. So, even for a rough estimate, you need at least some assumptions.

Sensoric access

If you include sensoric access (view and audition), it may be easier for parents inside the house to observe their children playing outside, than for their children to see their parents in the relatively dark interior, or peeping through the curtains. The children may not hear their parents calling them from the house, if they are surrounded by street noise that is closer to the children than the parents. The parents may hear their children easier from their quiet area than the reverse. The calculation of visual outward access per area, known as Isovist

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[a] Huffener(1977) in: Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis

calculation, cannot easily include these kind of contextual parameters such as differences of available light or closed curtains. But still, you are painfully aware of sensoric access when you close the curtains or go to bed while the neighbours have a party. Even if you cannot calculate access in all of its meanings, its rough estimation remains a crucial design variable for locating separations and connections in a drawing.

Orientation$_{10m}$

The orientation of an area with the sun, the wind, the plantations, gardens, streets and other buildings, influences every access type. But, two areas with the same access may still have different orientations by design. That is why orientation should be treated as a separate design variable R=10m. It is important for many areas, such as streets, gardens, playgrounds, the perforations of a façade, the rooms behind them and the galleries or balconies attached to them. Orientation, then, is more than the directions of a wind rose. You have to take other environmental objects within a radius of R=10m into account. It is not easy to name intermediate values between the extremes, 'undirected' and many-sided 'directed', and organize them in such a way as to balance the extremes. A building should be open on at least one side, in order to provide physical access to public space. The position of a main entrance is crucial. Its orientation often determines the 'front façade', but that is not necessary. The front façade receives more meaning at a R=30m scale.

Climate$_{10m}$

Buildings are primarily intended to exclude wind, moisture, and rain, and to stabilise a useful inside temperature. However, the inside climate of a building may differ per room, and the micro-climate in its immediate environment may vary. There are many unnamed in between values between 'stable' and 'variable', useful for environmental diversification.

Boundary Richness$_{10m}$

In an urban environment you mainly find sharply separated boundaries, such as walls with sudden changes of altitudes or sharp boundaries, between paved and unpaved surfaces. In ecology, vague boundaries are known to produce many in between values that are utilised by different (often rare) plant species. Wide transition zones with vague or curved boundaries between wet and dry, acid and alkaline, more and less nitrogen and so on, are called 'boundary rich'. However, a designer seems to love sharp boundaries, in order to develop clear drawings that allow them to clearly convey their ideas to the client. It could be worth the effort to search for opportunities to broaden boundaries. Even humans like ambivalent micro-environments between sun and shadow, windy and windless, noisy and quiet, wet and dry, odourless and fragrant. It decreases the many forced choices that are usual in their daily lives.

Information$_{10m}$

Information$_{10m}$ has different contents when compared to the Information$_{1m}$ already discussed earlier in on page 119. I will mention examples from larger levels of scale (i.e. R > 10m), and even concerning its form, in order to clarify its possible role in a radius R=10m.

Recognition and surprise

An environment$_{10m}$ may contain homogeneous, repetitive or mixed information of all kinds. Too little information is experienced as boring, too much as chaos. A balance of recognition and surprise between these extremes is aesthetically appreciated (see *Fig. 6*). But, that is personal, and it is dependent on one's recent experiences. If you travel trough a sequence

of surprising environments, you appreciate recognizable stretches situated in between, in order to recover from that surprise and to become ready for the next. Otherwise, its sequence becomes chaotic, and without anchor points. A surprising environment$_{10m}$ may be accentuated and compensated for through the provision of recognizable adjacent environments$_{10m}$. The result, then, is recognition$_{10m}$surprise$_{10m}$recognition$_{10m}$.
This creates diversity in a radius R=30m. This diversity$_{30m}$ is interesting for walkers, but not for cyclists, if you repeat the same diversity$_{30m}$. The same sequence constantly repeating becomes boring for cyclists, if they move three times faster than pedestrians. They may need a surprise every 100m. This diversity at$_{100m}$ (recognition$_{30m}$surprise$_{30m}$recognition$_{30m}$) requires some homogeneity$_{30m}$ to experience the difference of environments$_{30m}$ and to sense the boundaries they are passing. The same story repeats for car drivers appreciating surprising diversity$_{300m}$,and consequently is alternated by recognizable homogeneity$_{100m}$.

The distance of surprise

To summarise the preferences of recognition (r) and surprise(s): walkers like $r_{10m}s_{10m}r_{10m}$, cyclists $r_{30m}s_{30m}r_{30m}$ and car drivers $r_{100m}s_{100m}r_{100m}$. Looking at these formulae you may identify a problem. Car drivers like two times 100m repetition r to become surprised s (or awakened, aroused) by the third 100m stretch. That is once per 300m. But, cyclists want to be surprised once per 100m after two times recognition. And if you would provide that kind of diversity, then the walkers are disappointed, because accepting two times recognition$_{10m}$ they want to be surprised once per 30m before they become bored. The solution is simple: make another *kind* of diversity at each scale. For example, make the surprise$_{30m}$ different by another kind of architecture, make surprise$_{100m}$ different by the kind of trees and plantation and make surprise$_{300m}$ different by passing a facility. You also can incorporate remarkable points or big signs every 300m, less remarkable ones every 100m and even smaller ones every 30m.

Spatial Rythm$_{10m}$

In poetry, stress patterns are known as iamb (rs) trochee (sr), spondee (ss), anapaest (rrs), dactyl (srr), amphibrach (rsr). The examples above may advocate the last three, but less intense surprises allow the first three to alternate by two or more intense surprises, even four or more. In poetry, rrs, srr and rsr are different depending on how the verse rule starts. In music, there are time signatures and rythms, and at a larger time scale, themes and variations. Melodies and themes are seldom repeated more than three times before something changes. If the above mentioned approach for distributing information by spatial design could produce an appropriate environmental diversification in larger radiuses, what then is an appropriate rhythm$_{10m}$?
Numerous façades have a front door and two windows at the ground floor. The information density is highest at the entrance. The front door has different profiles, a post box, a nameplate, a bell, a lamp and so on. It is either flanked by windows as an amphibrach, preceded as an anapaest or followed as a dactyl. There is often a sequence of road-garden-building perpendicular to the façade. But, there may be many more variables to name.

Back to content

However, the *distribution* of information in space approaches the subject of the next chapter (form). The subject here should be the *kind* of information that may be distributed in space. In the examples above, information is related to the different kinds of Urban Functions$_{300m}$, Plantation$_{100m}$,Architecture$_{30m}$, and the Land Use$_{10m,}$ such as paved surface, garden, built-up, the Openings In The Façade$_{10m}$ such as doors, windows, post boxes or Attachments$_{1m}$ such as lamp, bell, nameplate. All of them can be distributed in space between the extremes of dispersion and accumulation. How to name the variables of information enabling environmental diversification in a radius R=10m? ‘Information’ may be a coordinating variable that includes every other variable. But here its familiarity between recognition and surprise is emphasised.

Territorality$_{10m}$Regulation$_{10m}$ and Control$_{10m}$

, Any individual, family, tribe or nation has territorial claims with biological roots. Their territory is their familiar and safe environment that is defended against outsiders. The familiarity with your home makes daily routines efficient, the safety of locked doors enables a defenceless sleep. But, leaving your home, you enter a collective territory with other rules. Land and buildings are still the most literal territories that are owned and defended by someone, but people easily move and sell them in exchange for money. For humans, capital or moveable property is part of their ‘territory’, and is not to be appropriated by others. In modern society, the boundary of a private territory is clearly outlined and administrated. The rest is collective or ‘public’ space.

Private and public

The difference between public and private environments is experienced as self-evident, mainly visually clear and subject to different kinds of regulation and control. Different environments may have different regulations. Roads may have other regulations than parks or private plots. In a residential area$_{10m}$, these differences are shown by different kinds of surface for cars, walkers, greenery, private gardens (often fenced), and built-up areas. The roads are regulated by traffic rules, which are embodied locally through traffic signs and ~lights. In pedestrian areas, cars and bicycles are not allowed. You cannot enter private gardens if you cannot clarify your intentions and purpose. When entering a house, you have to know its particular rules. Perhaps you are not allowed to smoke, perhaps you are supposed to take off your shoes.

Regulation and control

In public space, you can recognise regulation through traffic signs, different kinds of pavement and fences. The observance of collective settled rules is controlled through collective executive powers, such as a police organization, or an army, based on law. It is often obvious what is allowed and what is not allowed. Control in private territories is mainly left to its owners, recognisable by many details, either written or depicted announcements (e.g. beware of the dog, no entrance, private, bathroom, no smoking allowed). There are, however, interesting in between-areas where it is less clear how to behave. It may be a designer’s challenge to detail the R=10m environment properly according to this variable.

3.6 Design variables R=30m (10 - 100m)

	0	
Sun$_{30m}$	morning	evening
Altitude$_{30m}$	low$_{30m}$	high$_{30m}$
Articulation$_{30m}$	horizontal	vertical
Water$_{30m}$	land	water
Coverage$_{30m}$	sky	roof
Plantation$_{30m}$	paved	green
Street Furniture$_{30m}$	kerb	lamppost
Formality$_{30m}$	street	backyard
Noise$_{30m}$	silent	noisy

Fig. 78 Example 60x60m[a]

Sunlight$_{30m}$
The sun is your main source of light. It colours your environment by an infinite number of shades that change per hour, per season and by occasional weather conditions. That is particularly the case in a radius of R=30m, where your range of view is between 10 and 100 metres. Façades at different sides of the street may look the same only for one minute of the day, but at any other moment they will be different. Then you have got a choice to walk in the sun or in the shadow. It would be nice to see the food stores in the morning sun and sunny shops for clothes and jewellery in the afternoon. I doubt if any planner takes that into account. There may be more to take into account than the position of rooms within a building to save energy. Careerists may like having access to the sun during their breakfast and in the garden in the evening. Familists like having access to the sun earlier in the garden and at dinner. The sun colours the memories of your parent’s home. It may diversify the dwelling types at both sides of the street. Anyone likes parking spots without sun and trees, except in winter. Then, the sun helps you clean your car from snow and ice.

Altitude$_{30m}$
At different floors, you have different views. It is most rewarding at street corners. There, higher buildings will overshadow less gardens or only the streets, if they are located at the right corner. Differences in building altitudes articulate a street façade. Design has its greatest freedom at the top of a façade. Relief at the ground articulates gardens and streets with sunlight, shadow and different views. Bridges offer exceptional points and curbs divide pedestrians from other traffic sources.

Articulation$_{30m}$
Sometimes I wonder why buildings and streets terminate through right angles. Corners where pedestrians and other traffic stop for a while to get an overview on the traffic from different directions are opportunities for articulation. Buildings seldom give way to views or emphasize the crossing, e.g. by vertical articulation of their surface, or making a step forward or backward. Buildings are predominantly articulated horizontally by their floors. But, if walkers like a surprise every 30m, why not give them some rhythm for their walk? It may give them an idea of progress in long, monotonous streets. Why not let them look upwards sometimes along the lines of a proud taller building, instead of always depressively looking downwards at the tiles they walk on, because there is nothing more interesting to see.

[a] Huffener(1977) in: Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis

Water$_{30m}$
Urban water is a barrier and a circulation means for boats, it moderates extreme temperatures. it stores and drains the water of heavy or enduring showers, and it may remind people of their history. It is dangerous for children, but it is also dangerous if they never get used to it. If there is enough space, then make gentle slopes instead of steep quays. It allows for a diversity of vegetation, and a diversity of leisure grounds, as well as a diversity of choices for people. The dynamics of water differs from the dynamics of roads. It is a strong variable to diversify environments, if you remember Venice.

Coverage$_{30m}$
Roofs on a building are accepted as self-evident, but covered outside places are rare. Umbrellas, parasols, covered terraces, shopping malls and bus stops show their need. Covered outside areas provide many in between values. Solar cells covering a promenade may provide the necessary economic incentive for the shaded space. Trees have provided covered spaces for millions of years, through their leaves filtering sunlight to the ground in many shades and degrees of coverage, reacting on a season that requires more light.

Plantation$_{30m}$
Where humans fail to diversify their environments, vegetation can. Plantations may give any place an identity. They provide shade from sunlight, shelter from rain and they cover the view of ugly or boring façades, empty streets or squares. Its own diversity in altitude, form and colour is inconceivable at any level of scale. Plants dynamics in the wind or per season remain fascinating.

Street Furniture$_{30m}$
The moment street lights start to compete with sunlight in the evening and people turn on their lights behind the windows, your environment$_{30m}$ is changed dramatically. It announces the end of a working day, the dinner, your leisure time. Do only traffic engineers care about the effect of street lights? You may remember your break at a public bench that was facing car traffic, instead of the park behind it. Who cares?

Formality$_{30m}$
Many buildings have a public front and an informal backside with a private backyard. Buildings are often grouped as urban islands in a network of roads that are visible in a radius of 100m. But, the enclosed informal world of gardens, sheds and back paths are separated from public space at a radius of R=30m. Sometimes you can find in between values of formality in the courts of almshouses that do not have motorized traffic.

Noise$_{30m}$
Contemporary traffic produces public spaces that are full of noise. Backyards, courts of almshouses, pedestrian areas and parks are quiet counterparts.

3.7 Design variables R=100m (30 - 300m)

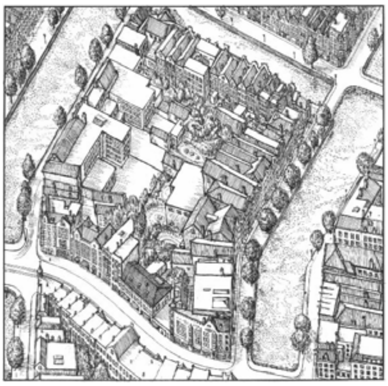

Fig. 79 Example 200x200m[a]

	0	
$Filling_{100m}$	space	mass
$Relief_{100m}$	flat	steep
$Lineage_{100m}$	directed	undirected
$Allotment_{100m}$	loose	attached
$Dynamics_{100m}$	quiet	busy
$Status_{100m}$	poor	rich

$Filling_{100m}$, Density

The extremes are a bare plain and a fully built-up surface. The Dutch auction building in Aalsmeer completely covers a a nearly 1x1km surface with one floor. But theoretically, there is no limit to the surface and the number of floors. Filling, then, is open ended at the ´mass´ side, but empty ´space´ is a clear zero-point. The density is often expressed in %built-up and %floor space, where %floor space / %built-up = the average number of floors. The %built-up has a maximum of 100%, but the %floor space and consequently, the number of floors, is theoretically unlimited. However, these density measures are averaged over an arbitrarily chosen surface. They do not give any impression about the dispersion of mass in space and their form, which are the core of design. But, the same data can be drawn as a dot map. If you choose dots with a radius r=10m, than they represent a floor space of πr^2, that is approximately 300m^2. You then can fill a 200x200m surface with 133 dots. If you want to design open space for gardens, public greenery and pavement for traffic, while keeping the same density, then you simply may remove some dots, and put them on top of other dots. The overlaps indicate where you need more than one floor. The built and vacant spaces now get a form. Your drawing begins to look more realistic as a rough sketch.

Relations with other variables

From such a sketch, you immediately get some impression of the other variables. You now can imagine differences of Size, Information, View , Visibility , Freedom Of Movement, Boundary Richness, Altitude, Water, Plantation, Formality, Relief, Lineage, Allotment, Dynamics, Status. It remains easy to change your sketch according to your imagination. You can see and even measure the increased diversity of densities by choosing an arbitrary surface and counting the dots. A computer will count the dots for you, if you select them.

Possible functions

But, your dot map enables more. On average, an inhabitant of the Netherlands uses approximately 30m^2 of floor space. The dots of 300m^2, then, represent approximately 10 inhabitants each. If you know from statistical sources that there are 16 million inhabitants, and some 13000 cafés in the Netherlands, then you may conclude that you need at least some 1250 inhabitants (125 dots) to support a café. If they are available in your map, then you can plan a café. But, there are statistics about any business that enable you to quickly estimate what other functions may be possible, in order to develop a functional diversification of the area. Do not forget to reduce the number of inhabitants available if you use floor space for non residential functions. A dot map communicates this way between numbers and form, empirical research and design.

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[a] Huffener(1977) in: Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis

Content or form?

Discussions on the possibilities of form and even function are subjects of the next chapters. Density is applicable to many kinds of content, such as buildings, floor space, inhabitants, trees, parked cars and so on. It limits the possibilities of form, but does it indicate form?. What, then, is the variable of filling varying between space and mass? Is it a form variable, or does it have a meaning as pure content, imaginable without any dispersion in space? That is also a valid question for the other variables, such as Relief, Lineage and Allotment below. The criterion is, *if it can serve as a legend in a drawing*. And, filling with mass or 'built up area' can serve as a legend R=100 indeed. But, 'density' may serve as a legend too, if there are differences within the frame of the drawing. That condition is the key for finding answers to these questions. It depends upon the scale, and a sufficient distinction of classes. I do not know of any density maps that cover only a radius of R=100m, which are mainly concerning one urban island. But, I know drawings$_{100m}$ where building masses and numbers of floors are dispersed as legend units. I call that a value of 'Filling', but that is an arbitrary name for something I want to indicate at this level of scale. 'Density', then, becomes a variable in larger radiuses where different urban islands have different densities. 'Form' is scale sensitive. What is 'form' at one level of scale may become an example of a category covering different forms in a larger radius. It can be represented in a legend. Molecules also have a form at the nano scale, but at the level of daily experience they become a chemical substance. This is an example of the category 'materials' in a larger radius.

Relief$_{100m}$

Differences in altitude at ground level, between different kinds of plantations and buildings, may extend, bound and diversify your views that you have walking through an environment$_{100m}$. At ground level, you may meet slopes, and even staircases, that separate buildings, gardens, sidewalks and streets. By climbing a bridge, you may have nice views. Specialists calculating wind velocities by looking from above, distinguish 'roughness classes', in order to classify different kinds of relief.

Lineage$_{100m}$

Curved building lines and adjacent sidewalks show façades from different angles. They reduce your view, and probably disturb your orientation. But, if the opposite façades of a street have a mirrored curvature or they draw back in the middle, then the diversity of street widths may provide space for some greenery and concentrated parking spaces. A narrower street entrance with larger buildings (keeping the ground floor free for providing an overview) gives the residential area an interior, an intermediate value of territory between public and private.

Allotment$_{100m}$

Allotment is primarily a question of form. But, the difference between attached dwellings and detached houses introduces a difference between introverted and extraverted environments. Detached low-rise houses with front gardens side-entrances (with larger windows at the front) and large backyards may be best located at the sunny side of the urban island. The shaded side, then, may be more suitable for introverted dwellings with parking at the street, oriented around sunny backyards. The morning and afternoon sun differentiates the façades of the buildings across the street, which contributes to a diversification of lifestyles on both sides of the street. The gardens are full of noise in the evenings, and children meet each other in the backyards the other parts of the day.

Dynamics$_{100m}$
The hierarchy of roads that stem from larger radiuses may border an urban island through 20m wide residential streets, 30m wide main streets, 40m wide district roads, and even 60m wide urban highways. They diversify the dynamics found at these boundaries, just as schools, shops, and other functions sometimes do. This diversification may require other filling, relief, pavement, lineage and allotment.

Status$_{100m}$
Wealthy people may choose wealthy, low-density districts or neighbourhoods to live. High density neighbourhoods, however, may offer them higher, but large houses without a garden with a view at the crossings of streets. An urban island that has high-rise articulated corners which give way at the ground, can extend from the building at the other floors through curved balconies giving passengers space and shelter from the rain. They may extend into the adjacent streets to get an even larger floor space. The lack of garden space at such corners may be compensated through sunny balconies and roof gardens with a view.

3.8 Design variables R=300m (100 - 1000m)

Fig. 80 Example 600x600m[a]

	0	
$Soil_{300m}$	rock	water
$Zoning_{300m}$	natural	artificial
$Density_{300m}$	vacant	built
$Access_{300m}$	pedestrians	cars
$Building\ Size_{300m}$	small	large
$Centrality_{300m}$	centre	periphery
$Pattern_{300m}$	repetition	variation

Frame Of *Fig. 79* Inserted

$Soil_{300m}$

Soil maps seldom contain smaller legend units than r=100m. Soil differences mainly become recognizable in a radius R>100m. They determine the kind of vegetation and foundation of buildings until some 30m depth. A zero-point of 'Soil' could be the barren rocks at the highest mountains. From there until the soils of the oceans, the 'Soil' variable ranges form gravel, sand, clay to peat and underwater sediments. Its value changes on average at a radius of R=1000km, but local differences appear everywhere in between. At the scale of R=300m, groundwater levels and the bearing power of sub-soils are already important additional characteristics of soil for agriculture and urbanism. Dikes, raisings, foundations and drainage systems may influence these characteristics artificially. Ditches or brooks at a mutual distance of 30m on the map may indicate peat, 100m clay and 300m sand.

$Zoning_{300m}$

An R=300m residential area is approximately 30ha. It contains at least 1000 inhabitants (often called a 'neighbourhood'). It may be the smallest surface to make a zoning plan. It may have a neighbourhood park R=100m, and it may share a primary school for 2000 or 3000 inhabitants with adjacent neighbourhoods. If 1000 inhabitants use 30ha, then there is $300m^2$/inhabitant urban area. However, in more central parts of the country and its cities, that may be $100m^2$. These neighbourhoods, then, may count 3000 inhabitants, enough for their own primary school, a café, some corner-shops, services and small businesses. The zoning plan may cover different fillings, densities, functions and their access.

$Density_{300m}$

Differences in %built-up, %floor space, and the number of floors may appear. If there are 3000 inhabitants using $30m^2$ of floor space, then you need nearly 10ha of floor space, or 1/3 of the total surface. If you also need 1/3 for public pavement and 1/3 for public greenery, then the remaining 1/3 private urban islands in a neighbourhood should have some 100% floor space. If you want private gardens, then the urban island may have 50% gardens and 50% built-up space. That requires an average of 50% built-up space in the urban island, and on average two floors, which is very common. The average %built up of the neighbourhood as a whole, then, is 50% of 1/3, or 17% of the whole. The average %floor space, then, is 100% of 1/3, or 33%.

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[a] Blaeu(1649)[a]

Access$_{300m}$
There is some evidence that collecting traffic flows every third road may be efficient from a viewpoint of time use and investment.[a] That would make, at average, every third residential street a neighbourhood road, every third neighbourhood road a district road, every third district road an urban highway, and so on. Looking at the topographical maps of the Netherlands, I could distinguish road hierarchies through the road widths. Between the buildings, there are strets and roads of approximately 20, 30 or 40 metres wide, according to their residential, neighbourhood or district function. Their width is often related to the functions they house, such as shops, services and businesses. A neighbourhood, then, will not only have residential streets. There is at least a wider neighbourhood road, and perhaps roads of higher order stemming from larger structures. Their presence diversifies the neighbourhood through the provision of values of access.

Building Size$_{300m}$
The buildings in a neighbourhood may vary in size. There may be detached houses, dwellings attached in a block, a school and so on. If the neighbourhood is the centre of a district$_{1km}$, a town$_{3km}$, a conurbation$_{10km}$, a province$_{30km}$, a region$_{100km}$ or even a country$_{300km}$, then much of the floor space will be used for shops, services, businesses and so on. That allows larger and higher buildings, which determines the form of the neighbourhood, and its composition. It increases the demand and the budget for design. The extremes are concentrated in a centre, or dispersed, in order to generate focal points.

Centrality$_{300m}$
Concentration or dispersion may be a question of form, but it also diversifies a neighbourhood between its centre and periphery. That contrast may be low if the neighbourhood itself has a peripheral position in a district$_{1km}$, a town$_{3km}$ and so on. But, if its location is in the centre of many larger radiuses, then the neighbourhood becomes diversified, due to its centrality$_{300m}$ (see *Fig. 80*). Until the 1600s in the Netherlands, the majority of towns as centres of a larger area had a radius of R=300m. Nowadays, these towns are the size of remote hamlets, and function as small centres of agriculture, often with a church as a central focal point.

Pattern$_{300m}$
Surfaces, lines and focal points may *repeat* every 100m. This causes *variation* in a neighbourhood R=300m (see *Fig. 7* on page 21) affecting the ‘image’ of Lynch[b].

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[a] Nes;Zijpp(2000) *Scale-factor 3 for hierarchical road networks a natural phenomenon?* (Delft) Trail Research school
[b] Lynch(1960) *The image of the city* (Cambridge Mass.) MIT Press

3.9 Design variables R=1km (0.3 – 3km)

	0	
History$_{1km}$	-300 000 000yr	+10yr
Occupation$_{1km}$	natural	urban
Network Density$_{1km}$	0.7km/km^2	7km/km^2
Intensity$_{1km}$	0hrs/yr	8 760hrs/inh*yr
Pollution$_{1km}$	clean	contaminated
Routing$_{1km}$	points	surfaces
Image$_{1km}$	homogeneous	heterogeneou s

Frame Of *Fig. 80* Inserted

Fig. 81 Example 2x2km

History$_{1km}$

History ranges from millions of years in the past, until approximately 10 years in the future. This is dependent on the time span of existing urban plans$_{1km}$. Existing plans for any future are a part of history. The remote past owes its interest to the sub-soil, and the more recent centuries to their subsequent remains and monuments.
Dutch gas is found in fields to a depth of 3km, R=30km wide and 300 million years old.[a]
The approximately 5cm/century subsiding lower delta has Pleistocene layers until 20m below ground level. Large buildings there may require long foundation piles to reach those layers with sufficient bearing capacity. The Pleistocene ranges from 3 million years ago until 10 000BC. The Holocene was the next period with human occupation. Archaeological remains may have been buried under layers of sediments after that period.
Some Dutch mediaeval towns at R=300m extended into a radius of R=1km after 1600. Extensions until R=3km appeared after 1900. Rapid extensions up to R=10km were developed after 1960. The urban surface then increased by ten each time, making them 1000 times larger than their mediaeval centres.

Occupation$_{1km}$

The occupation by humans is strongly related to the development of their technology. After a prehistoric occupation of scarce fertile grounds along waters for fishing and trading in the Netherlands, the Romans occupied the land until the river Rhine, building roads and canals. In 1000-1100AD, a substantial occupation started to transform moors into fertile polders created by farmers building dikes, dams and ditches drained into larger canals by windmills. Their outlets produced navigable waterways that provided the counts of Holland with enough tolls to decrease their taxes on farmlands. This introduced an early ‘republican’ spirit against any feudal rule pretending to own the land you have made yourself. It stimulated shipping, trade and industry, which was concentrated in a high density of defended towns. The lowland towns were drained through canals, structuring their extension, up to R=1km (see *Fig. 81* on page 134).
The resulting republic, the ‘United Provinces’ of the Netherlands’, occupied after 1600AD many parts of the world as colonies, founding 157 towns and trade settlements[b]. Their yields and the local energy sources from wind and peat produced a Golden Age. The power of this

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[a] Doornenbal(2004)*Geological Atlas*(Utrecht)TNO
[b] Oers(2000) Dutch Town Planning Overseas during VOC and WIC Rule 1600-1800. (Delft) TUDThesis Walburg Pers

early republic, however, declined after 1700AD due to a lack of manpower for the colonies and the army. The enlightened republican heritage had been exported just in time by Prince William III after his campaign through England in 1688. As its king, he allowed an unprecedented powerful parliament. This enlightening 'Glorious Revolution' enabled an early industrial revolution that was based on coal, the main source of energy of the 19th century. The declaration of independence of the Dutch Republic (1581) of William I shows similarities to Jefferson's declaration (1776). The USA then developed an economy largely based on petrol, the main source of energy of the 20th century. the Netherlands, however, became part of France after 1800AD until the battle of Waterloo. A short revival of royal centralism improved the Dutch infrastructure, preparing its late industrial revolution after 1850. After 1900, towns all over the country crossed the threshold of R=1km into a tenfold surface of R=3km. Transport technology based on petrol loosened the dependency of towns on having a location with adequate resources. After 1950, urban planning failed to stop sub-urbanization and sprawl across R=3km. After 2000, sprawl even across R=10km became accepted.

Network Density$_{1km}$

The Dutch 17th century lowland network of waterways and ferry services dominated national road networks, until 1850.[a] After 1900, a paved road network covered the country, crossing the rivers through steel bridges. The government gradually re-arranged the radiating road networks of towns into a grid, interfering the water network with bridges. After 1950, accordingly grid-like urban extensions$_{1km}$ hampered the pedestrian access of their district centres and schools. After 1960, the dominance of the car stimulated new separate radial networks for pedestrians$_{1km}$ and cyclists$_{3km}$, with smaller bridges and tunnels. District centres became pedestrian areas that were surrounded by parking and provision space. That story repeats for town$_{3km}$ centres$_{1km}$, , and is sometimes separating these conflicting functions vertically. There, cyclists and pedestrians go upward with empty shopping bags, and downward with heavy ones.
After 1900, tree like drainage and sewage networks became accompanied by networks for water, energy and information supplies in the sub-soils of roads. However, these became separately planned and maintained by separate companies. The network density, then, may become a crucial variable for change and planning$_{1km}$ in the years to come.

Intensity$_{1km}$

The more and less intense use of public space starts to diversify urban environments in a radius of R=1km. If 2/3 of its urban space is public (2km^2), and it is used by 10 000 inhabitants for 200 hours per year each, then its public space is used 2 million hours per year. That comes down to 1 hour per m^2 per year! The rest of the year that m^2 is for the birds. You would not expect that, if you see crowds walking on a normal Saturday at 14:00hr in a district centre. But that intensity may vary by period per 24hr (night, peak hours), per week (working days, Saturdays) and per year (holidays, normal). Moreover, the time spent at different places may vary from 0 hours/m^2*year in quiet public spaces to some 150 in shops. If half of the 2 million hours per year spent in public space concentrates in a district centre, then there are 1 million hours/year spent there. If that concentrates in 50 weeks of the year, then there are 20 000hrs in a normal week. If half of it is concentrated on Saturday, then it is 10 000hr/Saturday, or some 1000 per hour. At the peak, between 14:00 and 15:00, you then may meet 2000 people or 33 per minute! You are not aware of the emptiness of public space if you primarily visit the most intensely used dots at peak hours.
The survival of many kinds of shops and services depends upon the intensity of the location.

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[a] Vries(1981) *Barges and capitalism, passenger transportation in the Dutch economy 1632-1839* (Utrecht) HES publishers

If one of the 10 people passing by your shop in a district centre spends 10 Euro, and you need 1 million Euro per year to survive, then you need 1 million people per year to pass by your shop. If they spend 1 million times 1 hour in your district centre every time they pass by your window, then you may survive. But if you are located one street further, you may not.

Pollution$_{1km}$

The reach of pollution by odour, dust, noise or danger seldom exceeds 1km from its source. The primary strategy to deal with nuisances is to mitigate them at their source. But, if the nuisances are unavoidable, then keeping a distance around the source or the victims reduces their effect. Avoiding vulnerable functions within the nuisance radius of a source is called outward zoning, and avoiding sources within radiuses around vulnerable functions is called inward zoning. Environmental regulations and measures decreased the many sources of nuisances, and reduced the size of their outward nuisance radius substantially. That allows more mixing of businesses in residential areas. But, even silent cars generate noise through their tires when they are on the road, and they become more dangerous if you cannot hear them approaching. Outward zoning and mitigating measures around traffic is still the most dispersed and space consuming effect of pollution in districts. Urban highways with noise-barriers require at least 60m between the façades, regional highways 80m and the largest highways 100m. But, you can still hear them at a distance of 1km. Completely silent areas have become rare, just like completely dark environments at night. Silence and darkness at night in natural reserves, then, should be protected by inward zoning.

Routing$_{1km}$

Finding your way in a district$_{1km}$ is enabled through the provision of recognizable points, lines, surfaces and volumes, as Lynch[a] elaborated as Paths, Edges, Districts, Nodes and Landmarks. They are most effective when one is walking within in a radius R=1km. In larger radiuses, your route along the roads and turning points is sufficiently directed by maps, signposts, or navigators. An electronic navigator in your car primarily announces the turning points, and tacitly shows the lines in between. The points, then, are the most important details to find your way. Lynch supposes that paths are the most important details for your total image of the city, but that image contains many routes. On a single route, you always move from a starting point into a destination, by passing recognizable intermediate points from one point to the other. However, ‘points’ may be crossings, roundabouts, or even squares with views in any direction. The points or locations, then, are extended or ‘labelled’ by these views. A passenger will explain the points you have to follow by their labels: “ … , and then you cross a large road with traffic lights. And then you see a blue building at your left hand. And then you reach a small square…”. You may remember the points by these labels, but you follow the points.

If the points of your route are recognisable through a detail, a particular building or even a large surface such as a square, then these points can have a different order, a different importance, or a hierarchy based on their size. In The distance of surprise on page 125 I suggested, then, to give them also a mutual distance, according to that order. For example, a surprising architectural detail every 30m, a deviating building every 100m and a square every 300m.

[a] Lynch(1960) *The image of the city* (Cambridge Mass.) MIT Press

$Image_{1km}$

The image of a $district_{1km}$,then, is determined by the number of substantially different routes that you can follow in the area. If they are all similar, the value is ‘homogeneous’, otherwise it is ‘heterogeneous’. The name ‘Image’ may be applicable at any radius, and it is perhaps not the best one to express the number of characteristic routes. But, the ‘image of the city’, in the context of iconic city marketing, is a well known concept that was developed by Lynch. However, in this chapter it is supposed to be most operational in a radius of R=1km, which is a 20 minute walk. The ‘image’ of a $town_{3km}$ usually does not emerge through its outskirts, but through its (historical) centre (‘city’), and that is at most its central $district_{1km}$. On the other hand, in a radius of R=300m, ‘routing’ is less important. A 7 minutes walk nearly covers the reach of your view. At that distance, you will seldom speak about ‘routing’, if it only covers two or three points (lines, surfaces). Such a small sequence is not specific enough to be distinguished from many other cities.

3.10 Design variables R=3km (1 – 10km)

	0	
Ecology$_{3km}$	lifeless	many species
Housing$_{3km}$	attached	detached
Agriculture$_{3km}$	fields	settlements
Technology$_{3km}$	energy	information
Economy$_{3km}$	consumption	supply
Meeting$_{3km}$	home	work
Culture$_{3km}$	traditional	experimental
Management$_{3km}$	laissez-faire	initiative

Fig. 82 Example 6x6km 1930[a]

Ecology$_{3km}$

Wild Life

If you count the number of wild plant species per km^2 in towns, then you may be surprised by the urban diversity of wild life. Surrounded by a fertilized agricultural ‘desert’ that has at most 10 wild plant species/km^2, a town$_{3km}$ may count more than 350 non-cultivated plant species/km^2 in its centre![b] That is more than you can find in many natural reserves. If the town is embedded in a larger conurbation$_{10km}$ (I will call such a town a ‘city’), then the area with the most biodiversity may not be in the busy, stony and ‘fertilized’ city centre, but in the more outward areas, in the city centre’s surrounding districts. That phenomenon may have emerged only since the urban environments became cleaner, but the apparent urban ecological potential may be explained by the local boundary-richness. Plants, insects and other animals may discover and appreciate the urban diversity, and the many transitions of sun, wind, water, soil and their rare combinations, easier than humans.

Human ecology

The human population created a diverse techno-sphere, full of physical separations at every level of scale. For millions of years, people have lived without them, in wandering communities of hunters and collectors. But, since the emergence of agriculture some 10 000 years ago (Neolithic Revolution), separate families occupied land and settled as private owners of durable farms. Through the development of their defences, fenced and stable territories no longer had to rely on larger communities for survival. Their surplus production could be exchanged through trades in markets. Markets produced a specialised population of traders and craftsmen in defended towns. Individuals diversified in separate shops and workshops.

Since the Industrial Revolution, individuals and couples with children were separated again from their larger families, in smaller urban dwellings. Their private lives were closed off from public space, and individuals of local communities became strangers, through fenced gardens, walls, locked gates and doors. Many tasks of the former extended family were farmed out in urban functions.[c] Education, care, and religion developed internal specialisations, employment and buildings, such as school, hospitals and churches, separated people from family life. Any urban nuclear family received its own specialisations. In order to buy goods and services required for survival, a family had to sell its specialised labour. The number of specialisations increased, and so did the size of towns, in order to

[a] Bonnekaart(1929)
[b] Jong(2011) Urban ecology scale and identity **IN** Bohemen**,** The Sustainable Built Environment (New York) Springer
[c] Mayntz(1955) *Die moderne Familie* (Stuttgart) Ferdinand Enke Verlag

house a 'sufficient' community of specialists that ensured their survival. A town, then, is a concentration of specialised people that 'sufficiently' provide each other with each other's immediate needs to survive. But, what is 'sufficient' if towns still need to exchange with their immediate or remote environment? Why, then, are villages so different from towns? Specialisation saves time, but it takes space. The larger a settlement becomes, the more self-sufficient it can be. But still, what is 'sufficiently' large.
It may have to do with the proportion of time that is spent for internal and external exchange.

Time management of consumption and production

Until 1800AD, mainly small towns (R=300m) provided their inhabitants with the sufficient specialised products and services that were needed for their immediate survival, within a 7 minutes walk. That still may be your walk to the nearest supermarket, but new technologies of transport and logistics extended your radius that was accessible in the same time. The time you need for consumption, and to collect the products and services you consume, has to be balanced against the time to produce your counterpart in return. The more specialised you are, the more you probably have to travel to produce it, leaving less time for consumption. To save consumption time you reduce the time to collect its requirements. You look at what is available in the immediate neighbourhood, your more remote district~, town~ and conurbation centre R={0.3, 1, 3, 10, 30km}. You visit R=300m several times a day (e.g. to bring and pick up your children), R=1km only once a day (the supermarket), R=3km only weekly (the town centre), R=10km only monthly (the city centre) and only incidentally larger radiuses. The time balance of settlements as a whole, between their time spent for external production and internal consumption, may show something similar. However, what you call the 'consumption' of a settlement, then, should include the internal 'production' and mutual deliveries in the local market. What you call 'consumption' of a family also includes the private 'production' of meals in the kitchen, and any other mutual delivery. The distinction between production and consumption, then, is scale sensitive. Micro-economics and macro-economics, then, are different. Both do not specify the mutual deliveries that are hidden in the consumption figures. However, just the mutual deliveries are crucial to understand how cities, conurbations and regions function. It requires complex input-output analyses of 'Meso-economics' or ecology.

Values of ecology

If the number of species per unit of surface determines the values of the variable 'Ecology', then the human species is one of the many species you may find in an urban environment. However, just as any species has a specialised role in an ecosystem, different people play different roles in a town. If you subdivide the human population of a town into different kinds of people, as if they where different species with their own role and mutual exchange in the system, then you may observe a kind of environmental diversification that is also relevant for physical design. Human ecology is a discipline stemming from the University of Chicago in the first half of the 20th century. It studied the distribution of people with a different age or status (wealth) in towns. For example, Burgess[a] supposed a concentric diversification around a Central Business District (CBD), ranging from a factory zone, a zone of transition, residential zones with working and higher class people, into a zone of commuters in the outskirts. Hoyt[b] supposed industry sectors that radiated from the CBD in the low class residential half of a town, and in the other half, a middle class residential area, and a high class residential sector. It is worth the effort to develop 'Human Ecology' as a variable in that perspective. Michelson[c] distinguished between different types of people based on their choice of dwelling types. Different dwelling types are often bound to different locations in

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[a] Burgess(1927) *The determination of gradients in the growth of the city* (American Sociological Society Publications)21 p 178-84

[b] Hoyt(1939) *The Structure and Growth of Residential Neighbourhoods in American Cities* (Washington) Federal Housing Administration

[c] Michelson(1970) *Man and his urban environment: a sociological approach* (Menlo Park, California) Addison-Wesley Publishing Company, Inc. Philippines

towns, as if they are different species in a landscape. Age and status are usual categories, but Michelson also could derive different 'lifestyles' from dwelling advertisements in journals. He distinguished advertisements appealing to 'careerism', 'familism' or 'consumership'. Careerists prefer fast access to their work, familists like quiet suburbs for their children and consumers like to go out in city centres. Looking at the survival strategies of wild plants, you can find a similar distinction between competitors, stress-tolerators and ruderals[a].

Agriculture$_{3km}$

An agricultural area is often a monoculture that cultivates or breeds one plant species, in order to export them to towns, other regions, and even overseas. The size of specialised farms may range from 1 to 200ha (2km^2). Their fields and pastures look like a patchwork of rectangles in a radius of R=3km (30km^2). Traditionally (until 1950AD), they had a small village as a central place, while six villages in a radius of 10km had a small town as a centre.[b] The Dutch Noordoostpolder has a radius of 10km, and it was clearly planned accordingly. The development of agriculture into larger units and markets by improved technologies can be observed in the next (Flevoland) polders in the South of the Noordoostpolder, which have larger towns. Between fields and settlements, a range of values may be distinguished.

Technology$_{3km}$

The use of energy is an indicator of applied technology. It may diversify the urban environment through the density of energy use. In 1974, I could recognise a Hoytian high class sector in Amsterdam plotting the energy use of families in the city. However, the use of information is also measurable nowadays, but that may unveil differences at a higher level of scale, as the use of twitter does on a map of Europe. But, most important for urbanism is the distinction of roads: residential streets, neigbourhood main roads, district roads, urban highways. In the Netherlands water management diversifies environments in a larger radius, if you plot pumping stations, dikes and polder levels. Industries and their risk zones, sewage systems, (semi-) public water, gas, electricity and information supply may diversify urban environments at this level.

Economy$_{3km}$

Micro-economics concerns e.g. the balance between demand and supply of specific products and services of individual enterprises. If there are national statistics about services available, then you can divide the number of national inhabitants by the number of specific services, in order to determine how many inhabitants you need to support one enterprise. You then may discover e.g. that a town of 100 000 inhabitants could support a hospital, a theatre, three swimming pools and so on. Macro-economics calculates the total earnings of families as Gross National Product (GNP). That should be equal to the total consumption (I), the taxes they pay (T) and the savings they bring to the bank (S). It should also equal the consumption of families (Cf) and government (Cg), the investments (I) of government and enterprises, export (E) and import (-I). It then studies changes in formulas, such as GNP=C+T+S=Cf+Cg+I+E-M, T+S=Cg+I+E-M and S-I=E-M. You may have some insight of these figures for 100 000 inhabitants *on average*, but it neglects intermediate deliveries between companies *within* the national boundaries, useful for urban design. If you take the boundary of a town, or a region, then you could determine these deliveries through Meso-economic input-output tables. They determine the economic requirements for urban

[a] Grime;Hodgson;Hunt(1988) *Comparative Plant Ecology* (London) Unwin Hyman

[b] Christaller(1933) Die zentralen Orte in Süddeutschland: eine ökonomisch-geografische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen (Jena) G. Fischer

infrastructure, be it roads, cables or pipes, relevant for their mutual location. Much energy could be saved if you would succeed to arrange energy-users in a temperature-cascade. Transporting heat is distance-sensitive. What then may be the values of economy between macro-economic consumption and micro-economic supply, relevant for urban design?

Meeting$_{3km}$

A town is primarily a place of meeting. There are many places for *planned* meetings, such as workplaces, schools and clubhouses. However, *accidental* meetings between people of different background are a broadly accepted source of new ideas, innovation and social cohesion. Alexander thoroughly advocated for the provision of places of accidental meeting at any level of scale.[a] De Hoog calls them ‘interaction environments’, and he describes different types and examples in the Dutch Randstad to be developed.[b] This provision requires a kind of urban diversity that invites you to leave your home, and to avoid loneliness, which is a paradoxical disease of our time. The accessibility for children, disabled, unemployed and old people, then, is crucial.

Culture$_{3km}$

The urban diversity between traditional and experimental environments is probably most apparent in a radius of R=3km. Designers are inclined to choose experimental values, but the increasingly different cultural backgrounds of many inhabitants raises a demand for the identity of urban islands$_{100m}$, neighbourhoods$_{300m}$ and even districts$_{1km}$, in a town$_{3km}$. A mix of different values *within* a radius of R=100m (an urban island or residential street) may not be the best level. Even if mixture at that level is often advocated by public management and government, it may lead to conflicts, rather than to social cohesion. This may separate the culture into other cultures. Giving form to the boundaries between homogeneous areas may be the crucial challenge for design, and the best location for accidental meeting.

Management$_{3km}$

The most obvious appearance of public management is the town hall of a municipality. But many public services, such as the police, the fire brigade, refuse collection, maintenance of public space and so on, should have local access points that are open for feed-back from the responsible politicians. On the other hand, an increasing size of a town may force it to split up a municipality into partial municipalities of a conurbation$_{10km}$.

[a] Alexander(1977) *A pattern language* (New York) Oxford University Press

[b] Hoog, C.M.d. (2012) De Hollandse Metropool, ontwerpen aan de kwaliteit van interactiemilieus (Bussum) Toth

3.11 Design variables R=10km (3-30km)

Variable	0	
Altitude$_{10km}$	centimetres	kilometres
Geology$_{10km}$	years	millennia
Water Storage$_{10km}$	0	1 500km^3/day
Landscapes$_{10km}$	natural	urban
Land Use$_{10km}$	0	many hr/m^{2}yr
Deliveries$_{10km}$	contribution	distribution
Demography$_{10km}$	homogeneous	heterogeneous

Fig. 83 Example 20x20km[a]

Altitude$_{10km}$

Altitude$_{10km}$ is definitely different from Alitude$_{30m}$. That is true for any variable that seemed to repeated having the same name at the beginning of the sections above. But Altitude$_{10km}$, is a good opportunity to refresh that awareness. Even the *values* high$_{10km}$ and low$_{10km}$ have a different meaning from high$_{30m}$ and low$_{30m}$. For example, if a radius of R=10km contains mountains, it becomes obvious that Altitude$_{10km}$ cannot have values, such as bridges and floors, as mentioned as Altitude$_{30m}$ on page 127. However, it is not only the order of size that makes them different. In lowlands, the small differences of altitude$_{10km}$ may be not visible, but they have a great observable effect$_{10km}$. Moreover, it is a design variable that should be manipulated regarding their effects. One of these effects is the natural flow of water. The course of brooks and rivers, and their treelike branched form is an immediate result of local differences of altitude. The local groundwater level determines if you could only breed cattle, or also cultivate crops, and if so, the kind of crops that you can cultivate. If the soil subsides for 5cm/century or even more on peat soils or by gas drilling, then that will have consequences for planning$_{10km}$.

Geology$_{10km}$

Geological differences in a radius of R=10km may clarify differences in historical developments at R=1km, as mentioned (see page 134). In the future, it may influence the costs of foundation, which is its chance of subsidence, to find valuable raw materials or archaeological treasures in the sub-soil. It cannot be designed, but it diversifies locations in a radius of R=10km.

Water Storage$_{10km}$

Climate change may force lowlands to store water from the rivers and the rain in cases of high runoff, heavy showers and slow outlets into the sea. If the runoff of the river Rhine multiplies by 8 once in 50 years, then 16 000m^3 water enters the Netherlands per second. It can fill a 1m deep reservoir of 1km^2 in one minute. Enduring showers of 30mm/day may add some 10 000m^3/second in the lowlands. The largest pumping station in Europe is on the coast in the Netherlands (IJmuiden), and may pump out 260m^3/second into the sea. That is

[a] Atlas van Amsterdam

only 1% of the water that fills the country. If the rivers take care of 10 000m^3/second without flood, then you still need a storage of 1 km^2 per minute in the kind of reservoirs mentioned. That is 1440 km^2 per day, or 5% of the country. This approximate surface size, according to the number of rain days expected, should be planned, in order to avoid floods at a radius of R=10km. On the other hand, water storage is also important for dry regions or periods, even in the Netherlands. Drinking water, then, is less a problem than water for agriculture.

Landscapes$_{10km}$

In a radius of R=10km, the diversity of rural and urban landscapes becomes observable within 20 minutes, an hour or three hours, respectively by car, cycling or walking. From the centre of Amsterdam, you may choose for water in the East, Waterland or harbours in the North, residential areas, parks and dunes in the West, and lakes in the South or heath land and villages on sandy soils in the expensive Gooi area (see *Fig. 83*). The other way around, you can choose to live in different landscapes within a distance of 10km from a city centre. However, not many conurbations or rural areas with a radius of R=10km can offer that choice. That may be a challenge for their planning and design.

Land use$_{10km}$

Little or no land remains unused by people. It is a theoretical zero-point of waste land. How to measure land use beyond that point of no use? Land use is mainly distinguished by functions, such as residential, recreational, traffic and work. But, the *kind* of use is the subject of Chapter 6. Instead of functional differences, you may choose the number of hours every km^2 is visited per year, similar to Intensity$_{1km}$ (see page 135). It may give a much larger figure for residential areas than for any other function. However, is visiting the same as use? You may use coffee plantings all over the world daily in your living room or work place. You then may choose the contribution to the GNP, or the value per km^2, of your legend units.

Deliveries$_{10km}$

In Economy$_{3km}$ on page 140, I mentioned the mutual deliveries between enterprises causing traffic and transport that could be influenced through spatial design (e.g. the idea of cascading on page 140). The delivery of goods and services from producers to consumers (distribution), and the delivery of labour from families to enterprises (commuting), both cause a different kind of transport and traffic. Together they are relevant for the location of different kinds of land use. In a radius of 10km, that could be studied in a more general sense of logistics than a detailed calculation of sources and destinations as usual by traffic engineers. It may come down to determine the flows around nodes as 'technological-logistical stretches', at different levels of scale. The efficiency of durable dependencies usually take time. It happens through incidental movements into locations that are more appropriate for inward and outward deliveries. Sometimes it results in concentrations of similar enterprises (Silicon Valley, greenhouse concentrations), stimulating innovation.

Demography$_{10km}$

The structural homogeneity of population, concerning age, status, and lifestyle, require specific lay-outs and facilities. In a map$_{10km}$, differences of employment may become observable, resulting in 'problem districts' asking for attention of government, planning and design. Structurally unemployed neighbourhoods and districts may receive more public meeting space, denser public transport facilities, and signs of municipal involvement.

3.12 Design variables R=30km (10-100km)

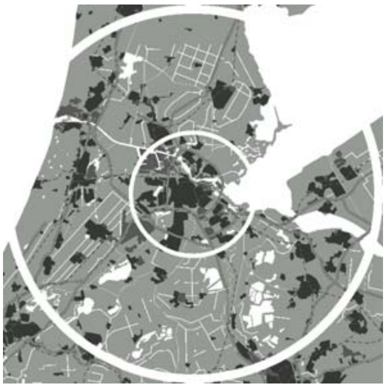


Fig. 84 Example 60x60km

	0	
Geomorphology$_{30km}$	erosion	sedimentation
Nature$_{30km}$	dry	wet
Waterways$_{30km}$	natural	artificial
Networks$_{30km}$	isolation	access
Transfer$_{30km}$	walk	fly
Risks$_{30km}$	nuisance	floods

Geomorphology$_{30km}$

The surface of the Earth between the lithosphere and atmosphere, between the mountains and coasts, shows its diversity clearly anywhere, even in a radius of R=30km. It is based on geological processes in the sub-soil, but it is finally shaped by sun, wind, water, vegetation, animals and man, resulting in erosion and sedimentation. Both may contain physical, chemical, biological and artificial processes. Subsiding lowlands are shaped by sedimentation. But the sedimentation has stopped, since winding rivers have been captured within dikes. Rivers and brooks cannot change their course anymore by flood the lands to disperse their deposits of sand and (where the water slowed down) clay. The locally raised land, then, forced the water to take another course, which in the end covered the lowest lands everywhere.

Centuries of vegetation filled the lowland with peat. But, man removed the vegetation, burned the peat and drained the land with straight ditches, at regular distances. Then, when water was pumped out, the land subsided even further. And, it still does. It then may unveil some former sandy courses of brooks that, through little differences of altitude, colour the vegetation differently, when viewed from the air. But mainly, the land equalised physically, chemically and biologically by its human inhabitants, in order to maximize their yields. However, centuries of bursting dikes, floods, and excavations left its tracks, moors, ponds and lakes. Locally, the land was artificially raised for terps, dikes or for building purposes, digging ground elsewhere. The result of these forces is a great diversity of water at the surface, or in the sub-soils. It resulted in a diversity of soils and wet vegetation. On the higher grounds, the course of the eroding rivers have been more stable, but in their worn out valleys, they may show a local diversity that are similar to lowlands.

Nature$_{30km}$

Differences in altitude, groundwater levels and soils condition the potential of different kinds of nature still allowed by (or useless for) human land use. Their sequence along, and perpendicular to the coast or rivers, condition many values of nature from brackish to fresh, from dry to wet, from sand to clay, from acid to alkaline, dynamic to quiet and so on. Planning and design may utilise these variables to extend their legends with intermediate values, and their infinite number of combinations.

Waterways$_{30km}$

Concave and consequently steep banks of rivers have offered historical opportunities for settlements everywhere. Their quays, small or large harbours are their gates to fishing grounds, regional or worldwide trade. However, to become a central place for trade, they required a bearing land surface with a radius, apparently until now, stabilizing at R=30km. The inland distance from the coast into Rotterdam and Amsterdam is approximately 30km, and the boundaries of their regions meet each other in between, at the same distance on the banks of the Old Rhine (see *Fig. 84*). The dams giving them their names dammed the smaller rivers Rotte and Amstel, which drained vast peat areas at both sides of the Old Rhine between the older towns of Utrecht and Leiden.
However, nearly everywhere in a radius of R=30m, you will find at least one river or main road that is fed by brooks or side roads from higher or inland areas.

A historical bridge or dam served the natural road along the larger waterway, where a town found sufficient bearing surface to develop into a central place. The same structure gets at any time or place a different form, but their crucial bridge or dam is often neglected and forgotten as the historical origin. They are outdone by the modern steel bridges that are able to cross the larger waterway as focal points in a larger regional system of highways and railways. The system of villages, towns and conurbations along waterways may show a regular sequence, but perpendicular to them, you may find a similar sequence making a difference between inland towns and villages, and those with access to the main waterways. Nowadays, the identity of towns is a crucial part of their city marketing. The differences given by nature may be a durable starting point for local identity: difference from the rest and continuity in itself.
Apart from the traditional sequence of settlements with quays and harbours, the remaining quiet banks of rivers have been covered by separate inland terminals for industry or trade, and by parallel and crossing roads. But, the in between values are part of the regional planning and design legends.

Networks$_{30km}$

A grid of highways or railways has different mesh-widths. At approximately every {3, 10, 30, 100, 300}km, there may be urban (every 3km), conurbational (every 10km), regional (every 30km), national (every 100km) and even continental (every 300km) highways with different design speeds and exit distances. If you leave one of the orders out, then local traffic will use roads of a higher order and speed than necessary. That requires more exits than necessary, and it may cause traffic jams.
Each order has its own network density. For example, if a regional highway network has meshes of (at average) 30kmx30km, then half of the roads (shared with the adjacent meshes) or 60km road length divided by the covered surface of 900km^2 , produces a network density of 0.07km/km^2. But, a different length/width proportion of meshes may produce the same density. Elongated meshes produce less crossings than square ones. A density of 0.07km/km^2 even may be produced by parallel roads without any crossing. Then, they have got their minimal mutual distance of 15km at that network density of 0.07km/km^2. The network density represents an amount of investment required.
These dry networks are superimposed on the older wet network of waterways. The combined meshes isolate the in between areas. Wet and dry networks may have a different form (grid or tree), but they have a surprisingly similar hierarchy and density per order. Wet and dry networks interfere with different mesh-widths, requiring a different number of crossings, bridges and tunnels. Elongated meshes require less viaducts, bridges and tunnels. That law is often forgotten in their mutual planning. Some of their crossings become transfer points from one mode of traffic to another, within walking distance.

Transfer$_{30km}$

The transfer from slow to fast traffic, from private car to public transport, from road transport to boats, from any wet or dry transport into aeroplanes require space and time consuming facilities, such as airports, railway stations, highway exits and so on. They nearly always need vast parking space, walking and waiting areas, offices and constructions. Waiting areas offer opportunities for shops and other public services. Transfer points, such as airports and railway stations, determine and diversify regional environments

Risks$_{30km}$

Regional risks range from earthquakes and floods to noise nuisance (a financial risk if it decreases the value of your property). You may draw contours around the sources ('outward zoning') or the vulnerable areas ('inward zoning'). Such contours limit the possibilities of future land use. The risk of disasters, such as earthquakes and floods, is calculated ranking the magnitude of earlier occurrences. For example, if magnitude 1 has occurred I time every year, 2 times every 10 year and 3 times every 100 year, then you may expect that maginitude 4 will occur every 1000 year. Such expectations are drawn in a so called 'Gumble graph', with the recurrence time 1, 10, 100, 1000 years on the x-axis and the magnitude 1, 2, 3, 4 on the y-axis. If you want to avoid these risks, then you have to pay according to their magnitude.
For example, if you want to avoid moderate floods every year, then you have to raise the dikes less than if you want to avoid a serious flood once in the 1000 years. The decision to determine if it is worth the effort to avoid floods, depends upon the costs of their damage d, and the costs to avoid them a. If d>a, then you may take according measures. However, both may increase with a larger magnitude that occurs less often. The damage you may expect once in the 10 000 years may be very large, but to avoid it now may cost even more. You then may accept a flood once in 1000 years. The Dutch Parliament once accepted serious floods once in 1250 years. Moreover, the expected damage may be different in different parts of the region. You may accept a flood once in the 100 years on agricultural lands, once in 1000 years in urban areas and once in 10 000 years at a nuclear power plant.

3.13 Design variables R=100km (30-300km)

Fig. 85 Example 200x200km

	0	
Altitude$_{100km}$	lowland	highland
Soil$_{100km}$	clay	rock
Vegetation$_{100km}$	wet	dry
Technology$_{100km}$	drainage	irrigation
Resources$_{100km}$	internal	external
Market$_{100km}$	local	international
Task Division$_{100km}$	agriculture	services

Altitude$_{100km}$

What is called high and low in a radius of R=100km has a different meaning and different effects from those in a radius of R=30m and R=10km. Lowland regions, compared to highlands, do have a different soil and vegetation. On average, they use different techniques and resources, resulting in a different task division, market, culture and so on. The Altitude$_{100km}$ differences do not *cause* these differences, they *condition* them through their location or distance to the coast. They cannot be changed through design, but they do condition the possibilities of planning and design. The lay-out of towns in the lowlands, with their canals, is different from towns at higher altitudes. The example of *Fig. 85* may seem rare, but mountainous areas do have their own relative 'lowlands' too. The cross section of the Alps is approximately 100km. Any time an inhabitant of flat lands chooses for holidays in the mountains, (s)he chooses for this kind of environmental diversification. And, that is a different kind of environmental difference than the difference between mountains and valleys that you may experience at your destination in a radius of R=10km.

Soil$_{100km}$

Average compositions of soil in a radius of R=100km diversify environments of R=30km, definitely in a different way compared to the differences mentioned in Soil$_{300m}$ on page 132. The nature differs, the roads are bordered by different trees, the agricultural land use differs, the different kinds of gardens and public green in towns are different. Design may cause local deviations from these general gradients of a larger scale. For example, many extensions of cities in the lowlands on peat and clay sub-soils are raised with sand as anomalies in the natural landscape. But, the value of diversity$_{100km}$ is increasingly recognised as a matter of identity$_{100m}$, and brought back in the detailing of their lay-outs.

Vegetation$_{100km}$

Landscape, park and garden architecture designers may choose trees and plantation more from a viewpoint of composition than ecology. But, the natural vegetation, and its accompanying populations of insects, birds and other fauna, may change substantially over a distance of 100km. The different ecological possibilities for design between lowlands and higher grounds may be overlooked, if they do not get a recognizable proper and more common name. However, the possibility of choice decreases, since we have already lost some 100 000 species. Our population required their space and resources.

Technology$_{100km}$

The majority of windmills is still found in lowlands near the coast. In the higher parts, they are less dispersed and grouped. In the lowlands, you may find pumping stations to regulate water levels everywhere. At the higher grounds, irrigation appears a more urgent problem. But, environments in a radius of R=100m still may differ most by their isolation and access to highways. At this scale, you still may distinguish the rare silent areas where you can experience full darkness at night. Aerial night photographs most clearly show the differences in illumination.
However, the development of technology has increased the dispersion of people, in order to realise nearly anything, anywhere. People and buildings have become more independent from their physical context. The social boundary conditions of economy, culture and management have become more important. Costs, fashions and initiatives determine the environmental diversity in a radius of R=100km, more than physical constraints. But that may change.

Resources$_{100km}$

A doubled world population will half the average surface per person in 40 years. Your resources will be a quarter of those of your parents, if their use per person is also doubled. If that continues, then those of your children will be a quarter of yours. The development of technology may have compensated for these kinds of decreasing possibilities up until now. But, if the free exchange of scarce resources begins to stagnate through local protection, then different technologies will diversify local environments again. One region will want to keep its gas, the other its coal. If China and Morocco want to keep their remaining phosphates for themselves, then agriculture will change dramatically everywhere else. If states begin to protect their rare earth elements, then regions will have to exploit their own possibilities, resources and technologies more intensively. But, one resource remains for everybody, be it differently available according to your distance to the Equator: solar energy. Any material can be recycled, if you have enough energy. Recycling, then, is a crucial regional industry that will be increasingly dependent on the local availability of energy.

Market$_{100km}$

Companies diversify the price of their products according to different local markets. These markets differ by many physical and social factors. Their differences may increase if they begin to protect their own resources, and consequently, if they have to pay more for those of other regions. Their internal and external market, then, will become even more different from other regions, according to their increasingly selective imports and exports. That will change their possibilities and environment. That environmental diversification may become increasingly observable, even at a radius of R=100km.

Task Division$_{100km}$

Regions recently may have become increasingly dependent on the global market. But, the symptom of an economic crisis every 40 years may be connected to a symptom of local protection and appointments with neighbour regions. Physical differences in a radius of R=100m may result in a task division that is increasingly observable in the differences of living environments.

3.14 Design variables R=300km (100 – 1000km)

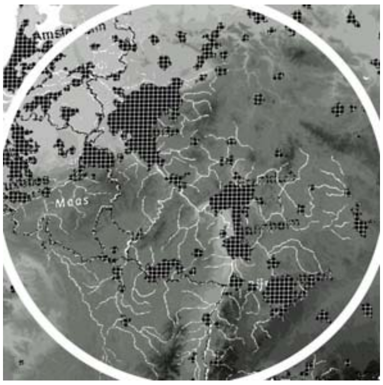


Fig. 86 Example 600x600m

	0	
Catchment Area$_{300km}$	mountainous	delta
Climate$_{300km}$	cold	warm
Economic Power$_{300km}$	dominant	serving
Economic Employment$_{300km}$	0%	100%
Legislation$_{300km}$	free	strict

Catchment$_{300km}$

The catchment area of a river mainly covers a radius of R=300km, ranging from inland areas to coastal deltas. It supposes a variation of altitude, it conditions many other variables, and it diversifies environments. Local climate varies with altitude. The population density and hierarchy of settlements followed the hierarchy of water courses for a long period of history. The Industrial Revolution, with its network of roads and rails, has disturbed that original order substantially. But, the historic layer is still observable. Particularly where resources in the sub-soil crossed the course of the main river, such as in the Ruhrgebiet, a substantial inland industrial power could develop. The lower reaches of the river into the coast, then, may have produced a different economy around its harbours.

Climate$_{300km}$

A radius of R=300km shows substantial differences in average climate. It conditions differences of agriculture, different ways of building (combined with different local building materials), public life and the composition of economic activities.

Economic Power$_{300km}$

If you compare Gross Regional Products in a radius of R=300m, then you may observe differences in economic power, differences in the availability of products and services, and accordingly, different environments.

Employment$_{300km}$

Already in a radius of R=100km, you may observe differences in employment, resulting in a different culture and political preference, with more or less public facilities.

Legislation$_{300km}$

Crossing governmental boundaries, you may experience differences in the environment that are related to (the historic development of) legislative rules.

3.15 Added diversities of form, structure and function

The combinatoric explosion of form

Two drawings with the same legend still may differ through the dispersion of their legend units in space, their lay-out, and their form. The number of different drawings you can make with the same legend depends upon the resolution of the drawing. For example, if your drawing has two locations, each to be filled by either red or green, then you can make four drawings (see *Fig. 87*, first scheme). If you have three locations to fill, then you can make 8 drawings (second scheme). With four pixels, you can make 16 pictures (third scheme). With 400 pixels filled by only two colours, you can make 10^{120} pictures, which is as many as there are atoms in the universe! A simple Windows icon with 256x256=65536 pixels and a palette of 33 colours, however, even has inconceivably more possibilities.

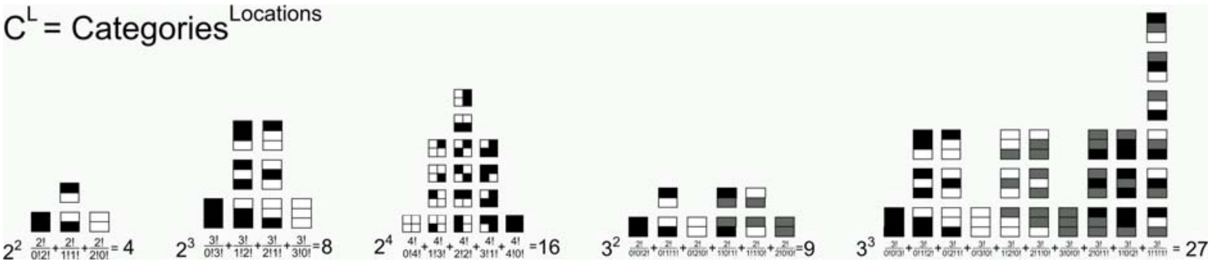


Fig. 87 Combinatoric explosion of possible forms with two or three legend units

If you fill two locations with *three* colours, then you can make 9 pictures; with three locations, you then can make 27 pictures (see *Fig. 87* the last two schemes). The combinatoric formula for the number of pictures you can make, then, appears to be $\text{colours}^{\text{locations}}$. The number of Windows icons you possibly can make, then, should be 33^{65536}. Most of them will produce a mess. Only some of them make sense, but even *their* number is still inconceivable.

#Possibilities[a] of a given proportion

In design practice, there may be a programme of required surfaces. For example, *Fig. 87* (third scheme) shows all the possibilities that can fill 4 locations with red or green. If red represents 'built-up area', then the programme could be 2 red, 2 rest. The number of design possibilities, then, is 4 x 3 x 2 x 1 / (2 x 1) x (2 x 1) = 6, or in mathematical notation: 4!/2!2![b].

> The division of two categories is called 'binominal distribution', with a general formula #possibilities = #locations! / #filled!(#locations – #filled)! Or P = L! / F!(L – F)!.
> That 'Binomium of Newton' is used in statistics to calculate the probability of any proportion. The more locations there are, the more the third scheme of *Fig. 87* will look like a probability curve.
> This proves that two legend units always offer the most design possibilities, if they are 50/50% available. If you can choose a programme yourself, then choose an equal proportion of the categories, in order to get the highest freedom of design possibilities!

The last scheme of *Fig. 87* shows all the possibilities that can fill *three* locations by red, green or blue. You could call that a 'trinominal distribution'. If you want to use all 3 colours at 3 locations, then there are 3!/1!1!1!=6 design possibilities (the last column of the last scheme).

---

[a] The sign # means 'the number of'.
[b] An expression 4x3x2x1 is usually called 'four faculty' and written as 4!. 'Zero faculty' is supposed to be one: 0!=1.

The many values that may take form

Fig. 74 showed 136 variables that could get a different meaning, at 6 different levels of scale, on average. That produced approximately 816 variables for environmental diversification. If any variable has on average 3 values that can be used as legend units in a drawing, then at one of the 12 levels of scale, there are on average some 816/12=68 legend units available at every level of scale. This is one of the 'palettes' that can be used to diversify the human environment through design. But, every legend unit may fill numerous locations. Suppose that you were asked to fill every square metre of land on Earth, with the 30 legend units of *Fig. 74* available for R=1m. Your freedom of design to make a picture of the approximately 150 000 000km^2 ,then, would be $30^{150\ 000\ 000\ 000\ 000}$ possibilities. Only one of these possible worlds is the present one (if 30 variables would be sufficient to describe its actual diversity). The possibilities for change, then, may be substantially reduced by the actual lay-out, and the time to realize your plan.

Values of different scale superimposed

Such an assignment is not very probable. But, suppose you get an assignment to design a neighbourhood of 30ha (R=300m with 72 legend units). Then, you still would have to choose from 72^{10} possibilities to make a rough sketch, which distinguishes 10 ensembles. In order to divide the ensembles of 3ha (R=100m with 51 legend units) further into 10 different building groups each, you would still have to choose 10 times from some 51^{10} possibilities, in order to distinguish 100 building groups. The legend units at R=300m, then, are superimposed on those of R=100m. Ten building groups *share* the characteristics of one of the ensembles of the neighbourhood.

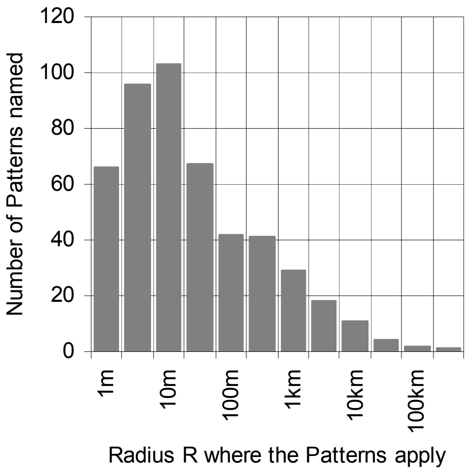
Overlays

But, also at the same level of scale, a location may share values of *different* variables. You then may make separate overlays, with each variable as a legend for the same area, in order to generate different insights from different variables. For example, if you make one map of a neighbourhood indicate the colours of its surfaces, and another indicating the hours of shadow in the summer, then their combination is what the inhabitants on average will experience visually. If there are more variables, the combined effect may make a combined map with legend units, such as 'red in the sun with low density', 'red in the shadow with high density', 'green in the sun with low density', and so on.
The more values of different variables you combine at each location, the less accessible your legend will be for a systematic empirical evaluation that relates variables with ranked values through multi-criteria analysis. They become less comparable to other examples, because their difference may be caused by more variables than those chosen for comparison.

Combined and separate values

The 253 'Patterns' of Christopher Alexander[a] can be interpreted as local designs, where many different variables are present and combined with one value each.
Alexander's 'Pattern language' ,then, suggests a legend with these Patterns[b] as legend units for drawings at a larger scale. The legend is the vocabulary of a drawing. It allows a designer to tell many stories in different directions. The same legend unit then appears as the same word in different sentences. *Fig. 88* shows an estimation of the radius R where these Patterns are applicable.
Fig. 89 shows the number of the extreme +1 values of *Fig. 74* for every R. The added value '+1' is 1 supposed intermediate value between the extremes.

[a] Alexander(1977) *A pattern language* (New York) Oxford University Press
[b] The concept of 'Pattern' is written here with a capital. In this text the term 'pattern' without capital will be used in a different sense as intended by Alexander.



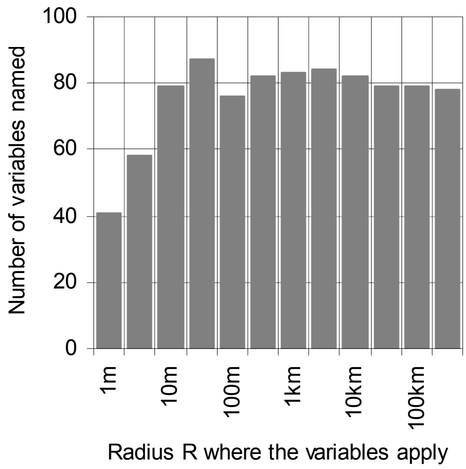


Fig. 88 The number of Alexander's Patterns per radius R

Fig. 89 The number of values per radius R

If any variable of *Fig. 74* would provide 3 values, then *Fig. 89* shows the number of values that could be applied within any radius R. For example, in *Fig. 74* the column R=1m represents the 11 variables already identified in *Fig. 75*. In *Fig. 89* , they are multiplied by 3, supposing any two extremes to enclose one intermediate value, thus arriving at 33 values.

More values to be explored

Alexander's Patterns indicate that there may be more relevant variables than identified in the previous sections. And, any design may produce new variables and values. For example, Alexander often refers to public meeting opportunities in residential areas that can be afforded through design. They are not mentioned at the variable 'Meeting' of *Fig. 74* That variable starts at R=3km, where 'Meeting$_{3km}$' has got the extreme values 'home' and 'work'. Alexander's Patterns, then, could be analysed further into named values and added to the list of *Fig. 74*, as Meeting$_{10m}$, Meeting$_{30m}$, and so on. It demonstrates once more, that the 80 variables, and their values that were identified in the previous sections, are not complete. And, they are not intended to be complete. They are intended to show how the 'palette' of a designer, the legend of a design, and the 'content' of environmental diversity, can be described by values of environmental variables. The list is large enough to become aware of their extensiveness, the number of their possible combinations in a legend, their impact on the (even larger number of) alternatives to disperse them in space, and the alternatives of form.

Relations between values

Based on that awareness, the next issue, then, is the relation of shared or adjacent values. Shared values at one location can produce synergy, as supposed in Alexander's Patterns, or they may hamper each other, forcing a separation. The same may occur if values appear as legend units that are accidentally dispersed in a drawing. They can meet each other at the boundary of two locations in many ways, as demonstrated in *Fig. 87*. To avoid nuisance both ways, and to stimulate synergy, their mutual relations can be studied. But, if there are 1000 values (see *Fig. 89*), then there are 1 000 000 relations possible to be studied.
It is self-evident that empirical research restricts itself to categories of values that can be ranked in a variable, as physics did with such impressive results for mass, space and time. *Fig. 74* names 136 categories of variables, each of which have an individual meaning, on average, at 6 levels of scale. Between these about 816 variables, approximately 600 000 relations are possible. That is a substantial reduction by 10, compared to the 6 000 000 relations between their values, if they would have 3 values each.

Reductions by ranking values

Empirical research then prefers quantification, but this still neglects many factors that designers have to include. Moreover, the ordinal ranking in variables relates only to specific pairs of values, such as x_1 to y_1, y_2 to y_2, x_3 to y_3 and so on. But, in a drawing, x_1 may meet x_2, x_3, y_1, y_2, y_3 and so on. The problem is well known in environmental zoning strategies. It is then solved through prescribed distances between different kinds of industries and residential areas, based on different kinds of nuisances, such as noise, odour or risk. But that is a limited xy-matrix of values, and it changes through developments in mitigating technologies. Design may introduce nuisance-mitigating separations, such as noise-barriers, that may reduce the necessary distance. On the other hand, it may introduce *connections*, in order to stimulate synergy.

It is worth the effort, however, to first explore the problems by studying the relations between ranked variables and non-numerical values . That will clarify the 'wicked' problems of naming variables and their values, in order to identify a relation that can be studied.

Relations between variables

There may be a positive relation between variables such as Access_{1km} and Noise_{1km} (the more access, the more noise). However, you can make a noise-barrier along access roads if that relation is undesired. That possibility changes the original probability by adding a *separation*. The prediction of noise, then is a 'self-destroying prophecy'. If there is a probable negative relation between Access_{30m} and Altitude_{30m} (the more floors, the less accessible), then you can make an elevator that changes that probability through a new *connection*. Connections and separations (structure) may change the primary probability.

It may be useful to separate these technological possibilities from 'primary probabilities' first. Many of the 600 000 relations may not be relevant. But, you could check them systematically in a matrix to determine if adjacent legend units in your design need additional structures, in order to reduce undesired relations, or to improve desired ones, instead of their primary probability.

Fig. 90 Primarily probable relations between variables in a field of possibilities

The first scheme of *Fig. 90* shows the first variables of such a matrix based on *Fig. 74*
The spots drawn in the matrix are tentatively elaborated in the next schemes.
Their location in the cells give an impression of the levels of scale that are involved, from the smallest left-above to the largest right-below, in each cell.
The investigator still is free to choose the relevant scale, the relevant values, and their mutual dependency, as a hypothesis for research.

Determining relevant and operational values

The relation between the first two general categories of *Fig. 74* (Access and Agriculture) already raises these questions of choice about their possible relations:

- at which levels of scale will such a relation be relevant and operational?
- which values, then, are relevant and operational for a relation at each level of scale?
- is one of the variables (y) dependent from the other one (x), or the other way round?

The second scheme of *Fig. 90* suggests an operational relation in a radius of R=300km.
At that level of scale, Access_{300km} may have a meaning for Agriculture, if you distinguish e.g.

values of Access by road, water or through the air. Which values, then, should Agriculture$_{300km}$ get, in order to suspect a relation with that interpretation of Access? I chose here autarkic (self-sufficient) and commercial agriculture as extreme values. Between these variables, there may be a relation: roads$_{300km}$ open up a market for commercial production. But, is that also the case for access by waterways$_{300km}$? Slow transport$_{300km}$ is not very appropriate for perishable products, and most of the agricultural products are perishable. However, if there are harbours$_{100km}$ and ships with cooling installations, then there may be a relation between waterways and an agricultural area, at a radius of 300km. But *without* such technical suppositions, a positive relation is less probable. Even more technical suppositions are required to find a positive relation between agriculture and air transport$_{300km}$. For example, there should be greenhouses, in order to produce light-weight agricultural products with high value, and an airport$_{100km}$. The usual mass of agricultural products by itself is not very appropriate for transport by air. The primary probability (curve in the second scheme of *Fig. 90*) ,then, is negative, if you do not suppose additional technical facilities and services. Additional techniques are shown as grey cells that are beyond the primary probability in the matrix of technical possibilities (the other cells). That matrix, then, is a search-field for design.

A search-field for design

If more access for commercial agriculture is desired, then the search-field for technical solutions is at the right side of the primary probability line in the second scheme of *Fig. 90*. The third scheme represents a hypothesis that detached buildings$_{100m}$ have a more expensive access$_{100m}$ than attached ones. They require more length of roads, cables, pipes, maintenance and travel time than attached buildings. There, the search-field for technical solutions is at the left side of the primary probability. The design challenge is then, to decrease the costs of access for detached buildings (the grey cell). The fourth scheme supposes less access$_{30m}$ for high rise buildings$_{30m}$, with a technical solution space again at the righ side, e.g. an elevator. The last scheme supposes a positive relation (not in the sense of desirability) between Access and Noise, with a solution space at the right side, e.g. a noise-barrier. In that scheme, shades of grey deviate from the primary probability. The shades of grey may represent the effort required for technical solutions.

Ranked values as a gradient

Some environments already show values in a ranked order, or they can be designed that way. For example, noise, light or heat may decrease with the distance to their source. The altitude of buildings may gradually increase towards the centre of a town, and slopes gradually differ from high and dry into low and wet. But, *designing* gradients seems to be unusual and difficult, since any intermediate value requires its own design effort. Contrast or repetition requires less effort. Sharp boundaries are easily drawn. Properties, then, are clearly divided. Gradual transitions between environments make calculated surface programmes uncertain. However, slow transitions of soil, moistness and altitude may have great ecological advantages. They offer many more species a chance for survival, than two homogeneous environments that are divided by a sharp boundary. Gradual transitions in residential and recreational areas offer more freedom of choice for people with different preferences. The experimental design of gradients may produce more intermediate values with unexpected possibilities. A gradually altering *form* (the altering dispersion and boundaries of one value or legend unit in space) introduces another possibility of gradation that is not easy to design. They will be elaborated in Chapter 4.

Non-ranked values
Empirical research may once have found 665 000 primary relations between values ranked in 816 variables, but then there are still ample 5 000 000 values left that occasionally can be designed next to each other, in a drawing that does not obey any pair-wise ranking. A value x_1 may meet x_2, x_3, y_1, y_2, y_3 and so on, in your drawing. Their relation cannot easily be studied, if there are no other existing examples to compare. They then create a unique situation, as one of the six million possibilities. Their effect cannot be predicted without enough existing examples. It has to be estimated by designerly intuition, or neglected.

Structural diversity
'Structure' is defined here as the way parts are separated and connected into a whole. If these separations and connections concern only a visual (or otherwise sensory) impression, then I would name it 'composition'. 'Structure' then is further restricted to the set of physical separations and connections that prevent or allow movement or change. In that sense, it may change the 'primary probabilities' , as distinguished before. Columns prevent floors from falling down, walls prevent the movement of air, and ventilation systems cause them. The human environment contains a great diversity of those kinds of technical connections and separations, thus preventing undesirable primary probabilities. These issues are the subject of Chapter 5. These structures make many functions in human life *possible*.

Functional diversity
Different human functions, such as living, working, recreation, and travelling, are dispersed over different environments. These environments are specialised and structured to serve these particular functions. But, some structures make many functions possible, and some functions may perform in many environments. 'Function' is an ambiguous term, even if it is defined here as 'working for people' , as it is elaborated further in Chapters 6 .

Intentional diversity
Human intentions are diverse. There are individual and collective intentions, vague intentions, multiple intentions, and intentions that are clearly formulated in their aims. Environments with the same content, form, structure and function still may differ by intentions and plans for change. These plans may have an impact on actual use and maintenance. That diversity is elaborated in Chapter 7,

Sequences of design
The orders of content, form, structure, function and intention may suppose each other in this sequence (see *Fig. 72*), but this does not determine the sequence a designer has to follow. The sequence of design is fundamentally free. Form may follow function, or the reverse, but the possibilities of form are practically infinite. This is probably why many designers start thinking about form with only a vague idea about intentions and functions. It gives them the greatest freedom to develop new ideas about the intentions, the intended functions, the possible structures, and their contents. Structuralists may start thinking about parts that add new parts to a whole, or the reverse. Functionalists may start closer to the client, by first studying their program of requirements. Contextualists may first start to study the location, its existing content and potentials. The client, the policy maker or the real estate manager may start to formulate intentions. But, not only the starting point is free. Any next step is free, too. Any sequence is free. However, at any stage, there are hidden suppositions about the other orders. All of them have to be clarified, once the design has to be realised. There, they have a *conditional* sequence (not a *causal* one). The building materials should be available, in order to generate a shape, by being properly assembled into a structure, before they can perform the functions that may serve the many possible intentions of the users. This is the sequence that was chosen for the chapters of this thesis.

4 Diversifying form

4.1 Distribution of content in space

Perception and construction of form

In this thesis, 'form' is a distribution in space. *What* is distributed only has to be different from its background. Without 'content', there is no 'form'. Its perception by your retina or skin is primarily flat. The imagination of a three-dimensional form then must have been constructed from different flat images. You can reconstruct the form mentally from a sequence of 2D impressions from your retina and skin, with additional information from other senses (motoric impressions, pain, audition, smell). To imagine an existing building 3D, you have to walk around it (or, with some experience, to study its two-dimensional elevations and cross-sections). Without motoric experience, a 3D concept seems to fail.[a] That experience is recalled as 'change', but change is simply a simultaneously recalled difference between the primarily planar diversities. In this Chapter, I will restrict myself to the diversity of forms in a plane (or a plan) and their change, (*diversification*) as a kind of difference.

One dimensional descriptions of form

Expressions in verbal language are one-dimensional. They report experiences (impressions embedded in mental reconstructions) in a strict sequence that cannot be understood backwards. Any sentence reduces these experiences into words that represent sets of similar objects and actions, which are recalled from earlier experiences. Verbal language produces strongly reduced (re)constructions of form. It reduces a four-dimensional experience into one-dimensional sentences. A picture can be read in any direction, and report many possible stories. Reading a picture, you may step sideways from your main story any time you want. By doing so in a text, you would get your wires crossed, and 'lose the thread'. To cover all the possible stories that can be read from a picture, you would need numerous footnotes, endnotes, attachments, references or links. Even then, however, you may catch only partly its content in a tree-like web. Even a computer screen, which builds its pictures through one line of pixels, can not include these cross-references.

Variables are words

The variables and their values discussed in the previous section are words. A variable is a construction, a ranked sequence of values. The source of any separate value may be a set of forms, which is abstracted into an idea (ειδοσ, image), and named as a word. Forms in-form, words re-mind. However, liberated from any particular observed dispersion in space, any value may obtain different imagined forms. Imagined 'form', then, becomes a construction. By inter- or extrapolating impressions, you may extend them into *possible* forms through design. 'Form', then, becomes a second-order variable, which is applicable to any content. Content can be distributed in space any way you want.

[a] Held;Hein(1963) *Movement-produced stimulation in the development of visually guided behavior* (Journal of Comparative and Physiological Psychology) 56 5 p 872-876

Ranking forms

'Form' includes the states of distribution of at least two values in space (e.g. black and white, 'form' and 'counter-form'[a] in *Fig. 91*) and contours (see *Fig. 92*).
A combination of both is called 'shape'. However, 'shape' requires sufficient accumulation of some content to observe a contour. 'Shape' does not fully cover the concept of 'form' if you want to include gradients such as the distributions of trees in a landscape, the built-up area in a district or the 'form' of a conurbation. Could you rank forms as values of variables such as 'State of distribution' and 'Contour'? And if so, what is their absolute value (a fixed standard, a 'zero-point') to determine the distance of any form to that most simple one?

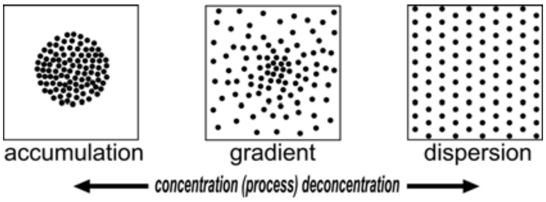


Fig. 91 Extreme states of distribution[b]

Fig. 92 Contours circumscribing equal surfaces

To rank forms, 'total accumulation' (minimal mutual distance) is a candidate for an absolute value of 'State Of Dispersion', and 'circle' is one for 'Contour'. After all, you cannot imagine a value that is more concentrated than 'totally accumulated', or a contour with a smaller perimeter / surface proportion than a circle. In *Fig. 92*, the surface of the triangle seems the largest, but it is equal to the surface of the circle and the square. Their contour lengths, however, are different. Triangles and squares have a larger contour length than a circle, but the minimum contour length will not be my final argument to identify the circle as an absolute value of form. The question is, whether all other forms can be described as deviations of 'totally accumulated' and 'circle' with a determined distance from these zero-values. Are there extremes at the other side (e.g. 'total dispersion' and 'square')? And if so, are these extremes perhaps more suitable to serve as an absolute value of 'form'?

Extreme values of distribution in space

According to nearest neighbour analysis, the regular hexagonal pattern of 100 dots of *Fig. 91* is even more 'dispersed' than a random one with its accidental local concentrations. Regularity, repetition, and equality is often concerned as 'order' (low disorder, near to zero entropy). But then, the 'total dispersion' of a hexagonal distribution would be the highest 'order'. That is contradictory to the thermodynamic concept of entropy, where concentrated solids have a higher value of 'order' (a lower entropy) than dispersed gases. The problem may be hidden in the level of scale that is taken into account, which leads to different meanings of 'order' and 'disorder' at different levels of scale (see *Fig. 7 Scale-paradox* on page 21). You can concentrate built-up areas in a radius of R=3km, and in the same time, de-concentrate it, at a radius of R=10km (see *Fig. 95*). 'Distribution in space', then. is scale-sensitive. If so, then 'form' and 'order' are scale sensitive too. Anyhow, 'total dispersion' is also an absolute value. You then can choose between 'total accumulation' and 'total dispersion' as a starting point to rank 'form'. Let us first look at extreme values of contour, and then come back to that choice and the issue of scale.

Extreme values of contour do not differentiate sufficiently

You may doubt that taking the circle as a starting point for producing deviations of other more diverse contours is the only or most effective possibility. The least number of *directions* that are needed to circumfer a surface is 2, resulting in a rectangle. Why not take the triangle, the square or the cube, then, as a starting point? The circle (or globe) and any

[a] If everything would be black, then there would be no observable form. That is why 'form' supposes at least two values. The inference is further focused on one of them as 'form'. If necessary, the other is referred to as 'counter-form'.
[b] 'Accumulation' and 'dispersion' will be used for the state, 'concentration' and 'de-concentration' for the change of state.

smoothly closed shape represent infinite directions in their perimeter deviating infinitely from the square. The number of directions, then, does not distinguish smooth shapes without sharp angles mutually. Any smooth shape has infinite directions in its perimeter.
The least number of *changes* of direction that are required to encircle a surface may be more effective. A circle has the least changes of direction (1), followed by a triangle (3) and a rectangle (4). The number of changes of direction plays a role in traffic engineering. For example, to describe a circle with your car, you only have to keep your steering wheel in the same position. If you are driving around in a triangle or a rectangle, you have to change direction 3 or even 4 times (see *Fig. 92*). You then may prefer a minimal *change* of direction as an absolute value, instead of a minimal number of the directions themselves. It has less suppositions. 'Direction' itself requires an external standard, e.g. 'North' to determine the other directions, such as 'East', 'West' and 'South', as deviations from 'North'. A *change* of direction is independent from any external orientation. It is a comparison in itself. However any smooth form deviating from a circle also has an infinite number of direction changes not distinguishing smooth shapes mutually.

An absolute value of the form variable

If contours are 'filled' with some content, the content of a triangle or square is more dispersed than that of a circle. If you consider the contour lines as a set of dots, then these dots are also more dispersed. 'Distribution in space', then, may also rank contours. In that ranking (otherwise than in *Fig. 92*), the triangle is more dispersed than the square. Since any contour also can be ranked by 'Distribution In Space', you can take that variable as the main variable of 'form', and even as its definition. 'Form', then, is the state of distribution of two values in space, in any case. That applies for dots, lines, surfaces and volumes.
Total accumulation also should have a circular contour, because any deviation of that form is more dispersed. If you accept the circle as the zero-point of Contour for different reasons, then total accumulation should be the most suitable starting point for ranking forms.

Contours determine the containing capacity

Different contours encircling the same surface may contain different quantities of equal circles. In *Fig. 93* left above and in the middle below, the shape of the containing circle causes an irregular packing, increasingly leaving space open into the centre. The square and the triangle leave space open at the boundary.
The capacity of the square is 80, but it would be 68 if the circles would be only little larger. The triangle could keep its capacity of 78 longer. A hexagonal packing is not always the most efficient packing depending on the contour. For the circle it would be less efficient (73, see *Fig. 93* left below). In any case, the relative size of the contained circles and the shape of the container determine the containing capacity.
Diversifying the size can optimise the capacity (see *Fig. 93* right below).
A Voronoi diagram[a] of the central points of the circles would transform them into surfaces-filling polygons with different surfaces and forms. Many natural patterns diversify cell sizes, in order to obtain a total coverage of the surface or the total filling up of a volume between the external boundaries (see *Fig. 94*). Non-hexagonal regularities appear at the boundaries, or along longer lines.

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[a] Try http://www.pi6.fernuni-hagen.de/GeomLab/VoroGlide/index.html.en

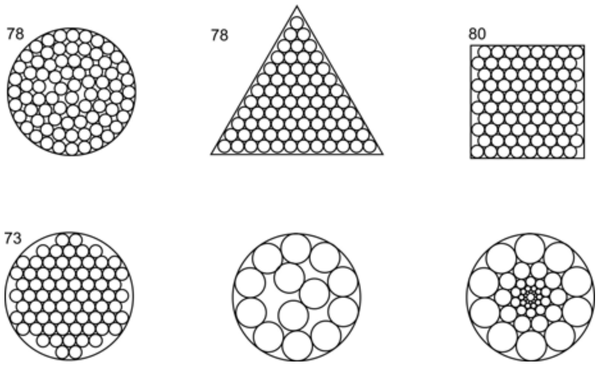

Fig. 93 Closest packing and maximum coverage of a contour with equal circles

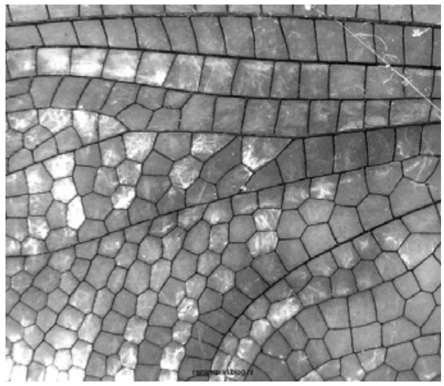

Fig. 94 The wing of a dragonfly[a]

Morphological outward or inward self-ordering should not be named as ‘self-organisation’, since ‘organisation’ implies a functional diversification between ‘organs’ or ‘organisms’.

Form and counter-form

Architectural drawings of a building show the dispersion in space of building materials, and a counter-form of air. An elevation may show a contour which is totally filled with building materials, against a background of air. A cross section shows an interior which is mainly filled with air, and is enclosed by the outer wall, the roof and the lowest floor. If you neglect the inner walls and inner floors, then the elevation and cross section, respectively, look nearly the opposite of each other: mass in space and space in mass. In the cross section, the air is central and the building material is accumulated in the periphery. The building material, then, may be more dispersed than the air of the inner space. But, it is still more accumulated than if the air and the building materials would have been dispersed and mixed into a ruin by demolition. Rebuilding the ruin primarily means accumulating the dispersed building materials, in order to restore the boundaries of an inner space. The building materials do not have the minimal mutual distance to characterize them as ‘total accumulation’, but they are still linearly accumulated as walls and floors. If the building would have the form of a globe, then the enclosed air would be ‘totally accumulated’, and the building materials a little less ‘accumulated’. The building materials are assembled, and eventually collected from an earlier dispersed state.

Drawing concentrates

The result, then, is *a concentration of both form and counter-form*. In a black and white drawing one of both colours primarily represents the form to be transferred (mainly black) with some visual coherence against the more dispersed background of the other colour (mainly white) as its counter-form. But, it also concentrates the remaining imaginable white dots, compared to the initially total dispersion of white, on the blank paper.
Architects often talk about giving form to *space* as a central issue, even if they only locate the bounding building materials in their drawings. That seems contradictory to thermodynamics, where solids are more concentrated than gases, by definition. But, that is reasoning at another level of scale, taking the molecule as a grain. Architects have a different legend, with a much larger grain than that of a molecule. Thus, distribution in space (i.e. form) is scale sensitive.

[a] Marrewijk(2012) http://ramireziblog.wordpress.com/2009/09/13/ramirezi-art-glazenmaker-in-lood-2/, coloured by a garden background.

4.2 Different forms at different levels of scale

Scale sensitive distributions in space

Fig. 95 shows four alternative methods to distribute 1 000 000 people in a radius of R=30km, from the most accumulated (aa) into the most dispersed (dd).

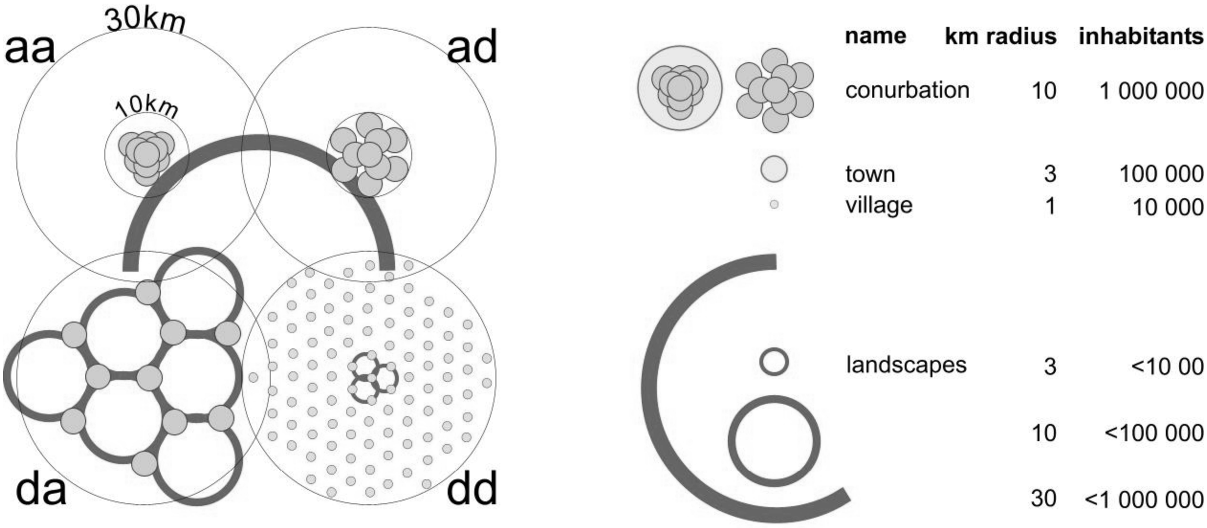

Fig. 95 Accumulation (a) and dispersion (d) at two levels of scale

The counter-form of open landscapes in between the urban areas follow that dispersion in increasingly smaller fragments. The intermediate distributions $a_{30km}d_{10km}$ and $d_{30km}a_{10km}$ show that dispersion at one level of scale can appear simultaneously with accumulation at another level (distribution accord). If you add a smaller grain (e.g. hamlets$_{300m}$), or a larger frame (e.g. a region$_{100km}$ with an accumulation or dispersion of conurbations), then the alternatives of form may extend into aaa, aab, aba, abb, baa, bab, bba and bbb (2^3 alternatives). I name these alternatives 'concentration accords' related to the 'variety accords' mentioned on page 21. These primary possibilities of Distribution may be combined into a Christaller- or Lösch-landscape[a], with their theoretical hierarchy of central places producing a higher density$_{30km}$.

Gros dots in order to compare Paris, London, Randstad

Paris, London and Randstad in that sequence show an increasing dispersion at two levels. To distinguish these levels, their actual form is reduced to the legend of *Fig. 95* in *Fig. 96*. The surface of a circle R=10km ($\pi 10^2 \approx 300km^2$) represents 1 000 000 inhabitants at 300m^2 urban surface/inhabitant[b]. A circle R=3km ($\pi 3^2 \approx 30km^2$) represents 100 000 people.
This dot map represents the number of inhabitants, much like a table would represent, but distributed in space as form. It is decimal. Any circle or dot can be divided into ten smaller dots, with a radius $\approx$1/3 of the larger one, representing 1/10 of its surface and inhabitants. In reverse, you can collect 10 concentrated smaller dots into a larger one. In *Fig. 96*, the inhabitants of smaller dispersed settlements are collected in virtual units of 100 000 inhabitants (R=3km). The resolution of the drawing, then, is limited to 3%, since it is the proportion between grain and frame (nominally R=100km, only partly shown in the figures). That resolution is appropriate to distinguish relevant differences of distribution (form) at two levels of scale. Accumulation is characterized by overlapping circles, dispersion by the circles' mutual distance.

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[a] Christaller(1933) Die zentralen Orte in Süddeutschland: eine ökonomisch-geografische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen (Jena) G. Fischer
Lösch(1938) The Nature of Economic Regions (Southern Economic Journal)5 1 p 71-78

[b] 300m^2/inhabitant is approximately the average use of urban space per inhabitant in the Netherlands (different per region), of which 160m^2 residential area including primary facilities (such as primary schools) and 140m^2 other urban functions.

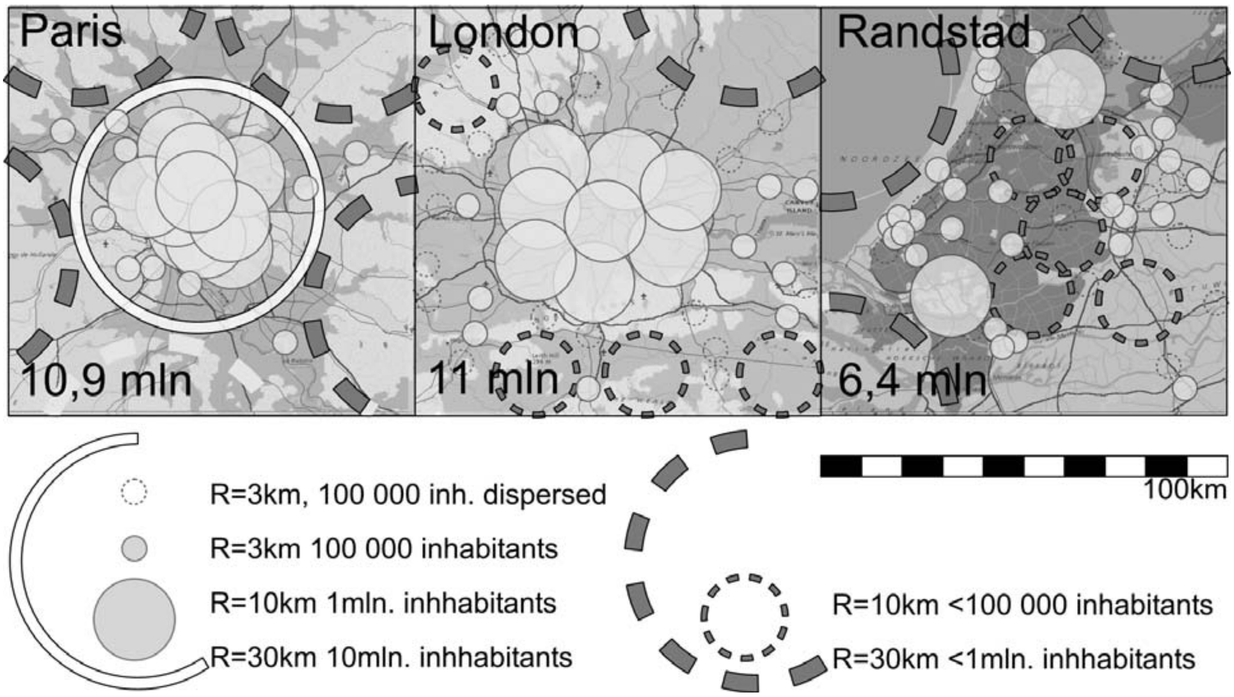

Fig. 96 Paris, London, Randstad 2000 in gross dots, also used in Fig. 55 on page 100)

The Randstad shows two conurbations that are separated by approximately 60km. They are then dispersed in a radius of 100km, but are still accumulated in a radius of 30km: $d_{100km}a_{30km}$. Paris and London are accumulated (overlapping dots) at both levels: $a_{100km}a_{30km}$. To approach the real form of the conurbations and towns more precisely, you may divide any circle further into 10 smaller ones, and repeat that operation to be even more precise.

Net dots in order to compare forms inside an urban area

Inside an urban area, however, the counter-form is no longer a landscape, but public space. The form, then, should identify the private space. This can be approached by smaller 'net dots' that represent *floor space*[a] for 1000 inhabitants (r_n=100m, see *Fig. 97*) or accordingly, 10 000 inhabitants (300m), 100 inhabitants (30m), 10 inhabitants (10m) or one person (3m).

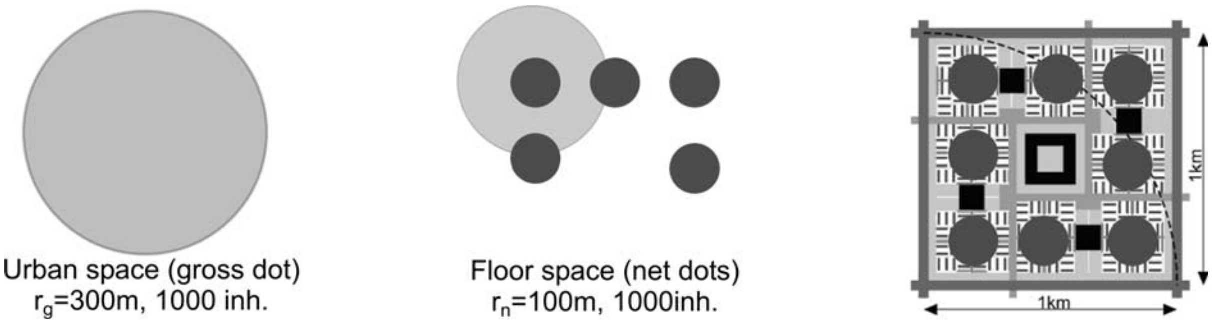

Fig. 97 Distribution of floor space reduced in net dots used in Fig. 56 and Fig. 62 on page 101

Choosing the proper grain at any level of scale makes the form of conurbations, towns, districts, and so on until even utensils comprehensible in their own right. For designing, a resolution of 3% (a sketch, the precision of *Fig. 96*, possibly colouring approximately 1000 locations) is sufficient. It prevents applying form legends and grammar at the wrong level of scale. Detailing and changing scale changes the legend, and changes the way of designing.

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[a] 30m^2/inhabitant is approximately the average floorspace/inhabitant.

Net dot maps for early impact analysis

Fig. 56 on page *100* and *Fig. 62 on page 101,* show the distribution of inhabitants in more detail than *Fig. 96*. By doing so, it unveils aspects of the actual and proposed forms that are still hidden in the rough representation of *Fig. 96*. A further subdivision of the net dots would have been superfluous for an impact analysis at that level of scale. The resolution is precise enough to predict ecological impacts and traffic flows, to plan the location of schools and other public facilities. From a dot map, you immediately can find the optimal location for any facility requiring 1000, 10 000, or any other number of inhabitants in a radius of 300m, 1000m, or in any other radius. If designers would draw dots instead of lines first, they would get a better feeling for numbers and distances. That is what form does. It determines numbers and distances, with impacts at many fields of interest. Moreover, it allows one freedom to connect or separate these located quantities by lines in a second stage.

Forms deviating from total accumulation

Detailing a distribution of quantities, by locating them more precisely, shows the actual deviation from total accumulation (shaped as a circle).
Fig. 98 shows the residential and job floor space of 1 000 000 inhabitants in Rotterdam, and some adjacent municipalities, as a conurbation. The 1000 *net* dots (100m radius each) represent the floor space of 1000 inhabitants each (supposing 30m^2/inhabitant). The grey dots tentatively locate 1000 jobs each.
The dispersed form of small net dots shows an elongated distribution that is caused by the river. The lines in *Fig. 98* divide the image in equal numbers (500) of black dots at both sides.The central R= 10km grey circle would be the totally accumulated gros dot of *Fig. 96*, including the urban space / inhabitant, according to the Dutch average (300m^2 / inhabitant).
In *Fig. 98*, we may distinguish separate groups of dots as components in a composition.
At any scale, compositions acquire their own variables (see *Fig. 63* – *Fig. 68* at p102 – 102).

Fig. 98 The distribution of inhabitants of Rotterdam conurbation 2010 showing its form

4.3 The distribution of lines

Hexagonal patterns

Paul Klee suggested a line to be a walking point.[a] The dots in the previous section represent surfaces (or volumes in cross-sections). They are usually designed and drawn by contours and lines, representing walls (separations), roads (connections), an effort to build, or an investment, which should be minimised. The smallest perimeter/surface proportion can be achieved through the use of a circle. A primary probability, then, is that the least length is built at the lowest costs. If adjacent surfaces share a common boundary, then a hexagonal pattern of boundaries is the second best.[b] This phenomenon is clearly shown by patterns of soap bubbles (see *Fig. 99*). Buchannon (1963) once proposed to pack neighbourhoods (R=300m) in a *hexagonal* pattern of neighbourhood roads.

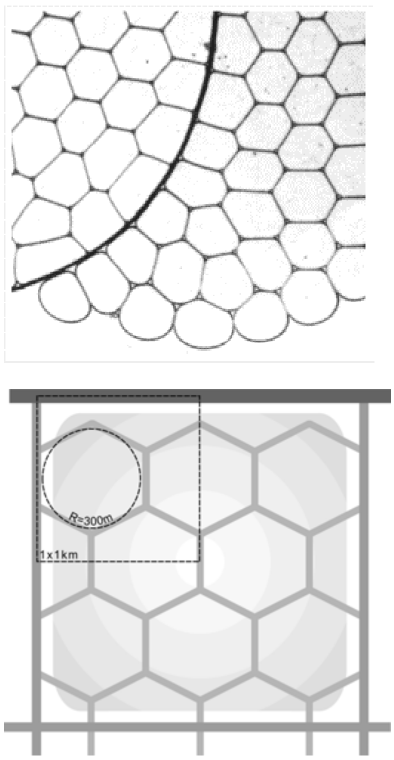

Fig. 99 Hexagonal network[cd]

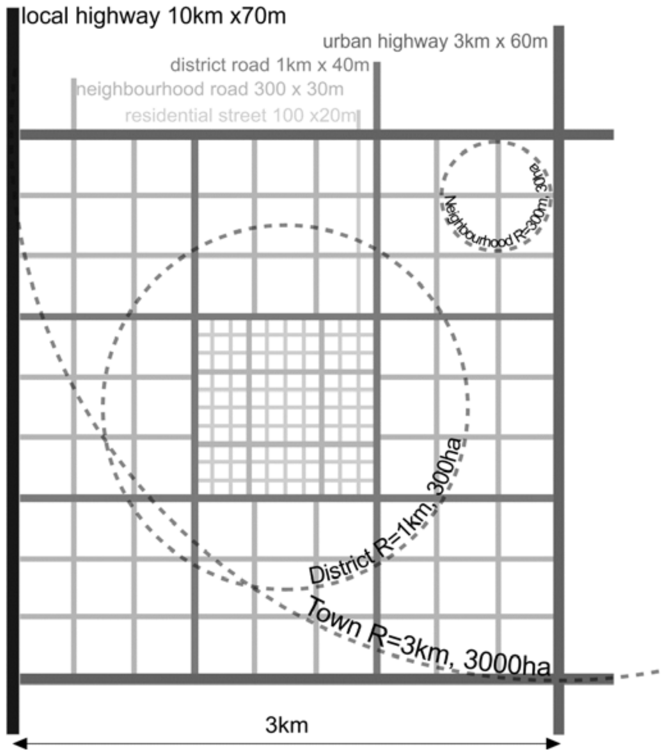

Fig. 100 Orthogonal network

Orthogonal preference

Why, then, does the third best *orthogonal* distribution of lines appear to be the most usual? At the urban level, stretched roads of a higher order for faster thru-traffic introduce a primary probability of rectangular connections, just as soap-bubbles re-arrange themselves into a rectangular pattern along a stretched line in *Fig. 99*. Morphological hierarchy straightens.

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[a] Spiller, J. (1961) *Paul Klee Notebooks Volume 1 The thinking eye* (New York) Wittenborn pages 78, 106, 123, 125 and 382
[b] In 3D there are many space-filling polyhedrons, see http://mathworld.wolfram.com/Space-FillingPolyhedron.html .
[c] Hildebrandt;Tromba(1985) *Mathematics and optimal form* (New York; Oxford) W.H. Freeman and Company
[d] Buchanan(1963) *Traffic in Towns. The specially shortened edition of the Buchanan report* (Harmondsworth, Middlesex, England) Penguin Books

Hierarchy

A road hierarchy often follows the principle that every third road acquires a higher order.[a] This seems also valid for wet connections. The semi-logarithmic range of nominal radiuses of *Fig. 18* (R = {1, 3, 10 … 300 000m}), classifies urban environments and variables. It also fits well with the mesh-width hierarchy of Dutch roads and waterways (see *Fig. 101*). Metropolises, conurbations, towns, districts, and neighbourhoods are divided by dry and wet connections. The mesh-widths of their main roads approximately equal their radius. An urban highway, then, may cross a town through its centre, in order to open it up radially or tangentially, and separate the peripheries.

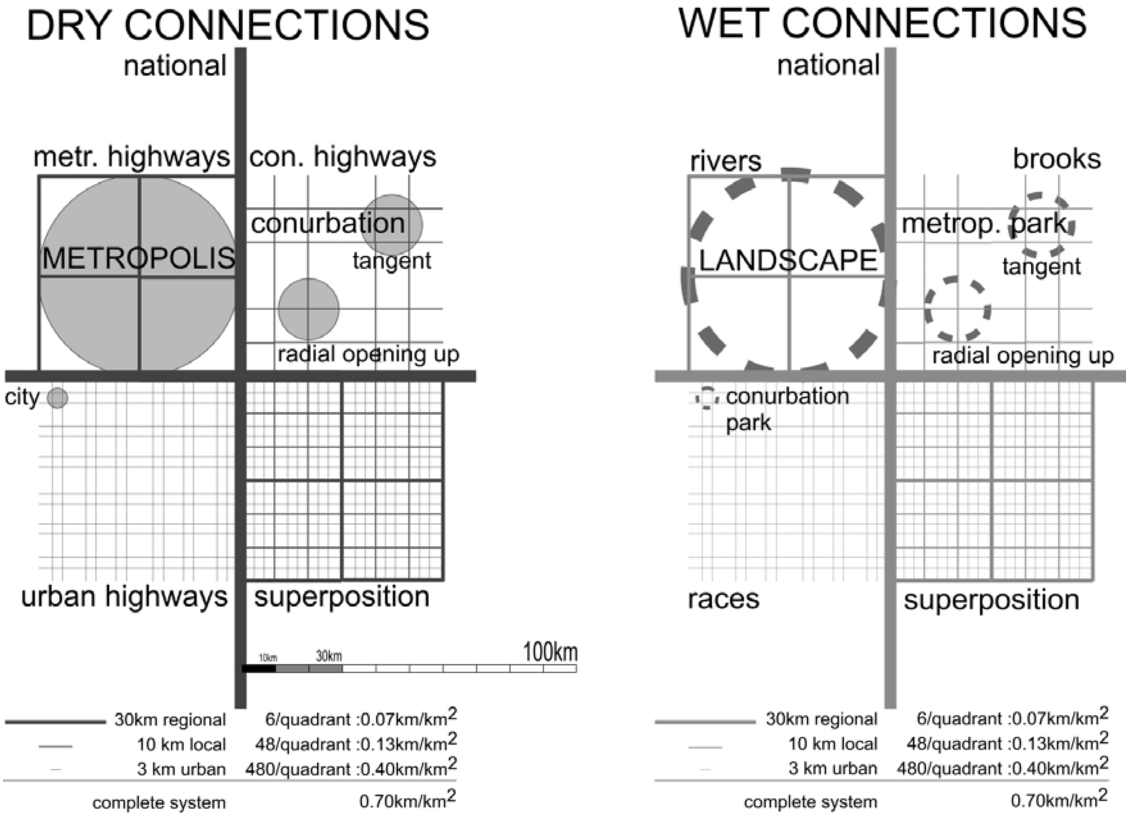

Fig. 101 Dry and wet connections

Superposition

The higher order is superimposed on the lower one, reducing the density of lower orders. For example, a neighbourhood road may replace a residential street. If the primary density of residential streets with a mesh-width of 100 x 100m is 20km/km^2, then that density has to be reduced into 13km/km^2 by the density of neighbourhood roads, which is 7km/km^2.

Elongating

Network density is approximately proportional to the network investments. By keeping the network density (and the investments) the same, you can elongate one side of the mesh, and accordingly decrease the length of the other side that is perpendicular to the first, into an elongated mesh (see *Fig. 102*). The curve represents any alternative that deviates from the square, and these deviations have asymptotes where parallel roads without crossings reach the same density. Any closer arrangement of lines, then, would produce a higher network density. Elongation of meshes reduce the number of crossings.

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[a] Nes;Zijpp(2000) *Scale-factor 3 for hierarchical road networks a natural phenomenon?* (Delft) Trail Research school

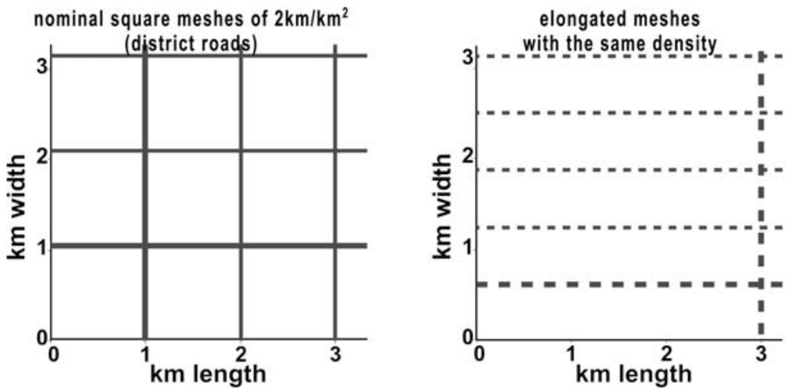

Fig. 102 Equal network densities

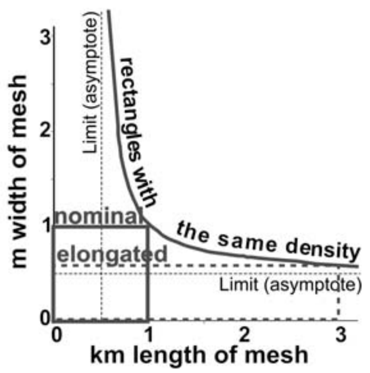

Fig. 103 Equal density elongations

Interference

Different networks, e.g. dry and wet networks, may interfere. That interference separates urban areas even more in segments, and it produces crossings between the different networks, such as bridges. Elongating the meshes, then, may reduce the number of bridges required. The substantial investments for bridges, then, can be reduced through design.

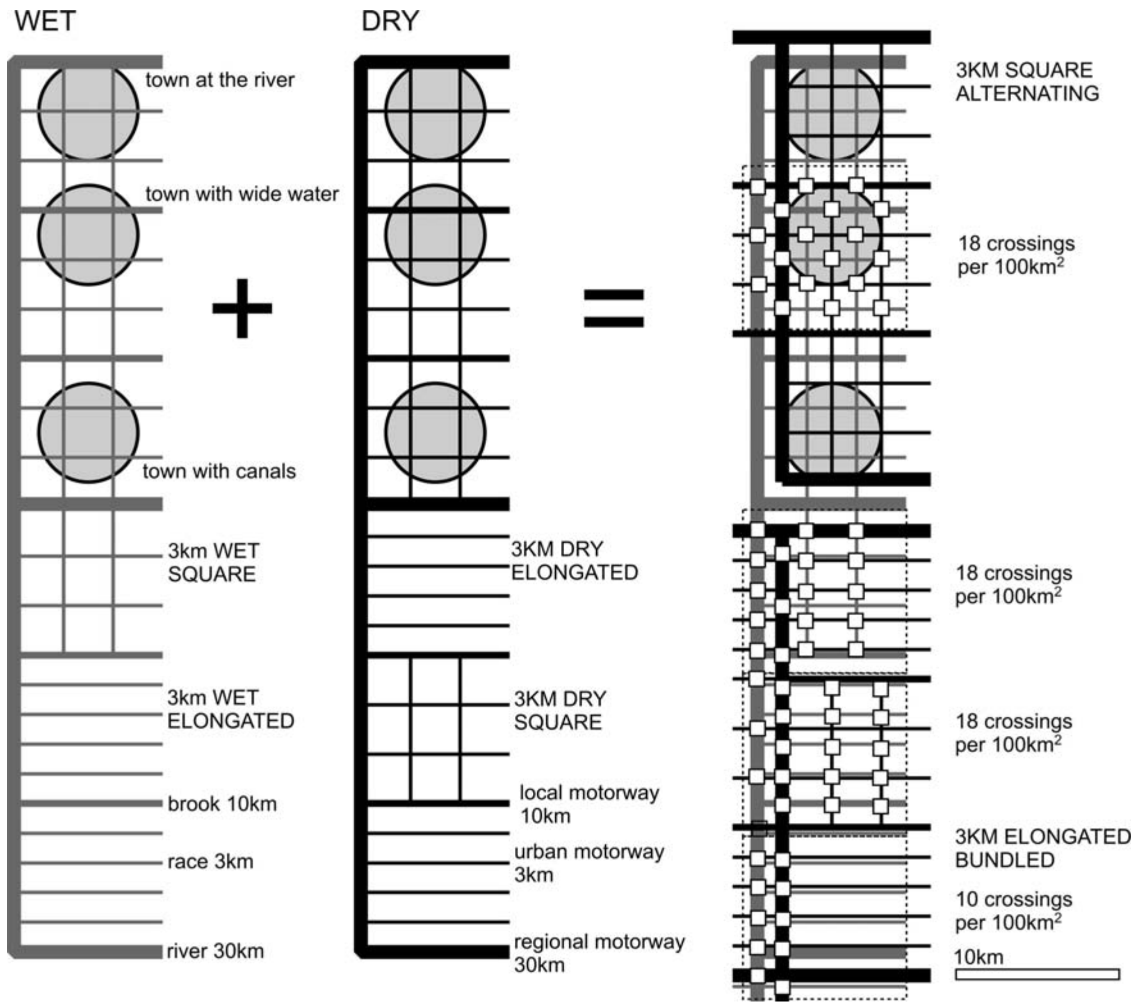

Fig. 104 Interference and reducing crossings

Composition on grids

Fig. 63 – *Fig. 68* on page 102 – 102, show compositions with a limited number of components. The components differ in content and form. At the same time, however, they should have something in common, in order to obtain a recogisable composition between other compositions. Separating or crossing lines may strengthen or weaken that composition.

For example, the identity of urban islands within an ensemble, of ensembles within a neighbourhood and so on, is supported or disturbed by street patterns. A regular grid of residential streets *divides* a district R=1km into equal urban islands R=100m (see *Fig. 105*). This still may characterise the district as not having any environmental diversification of neighbourhoods at R=300m, between R=1km and R=100m.

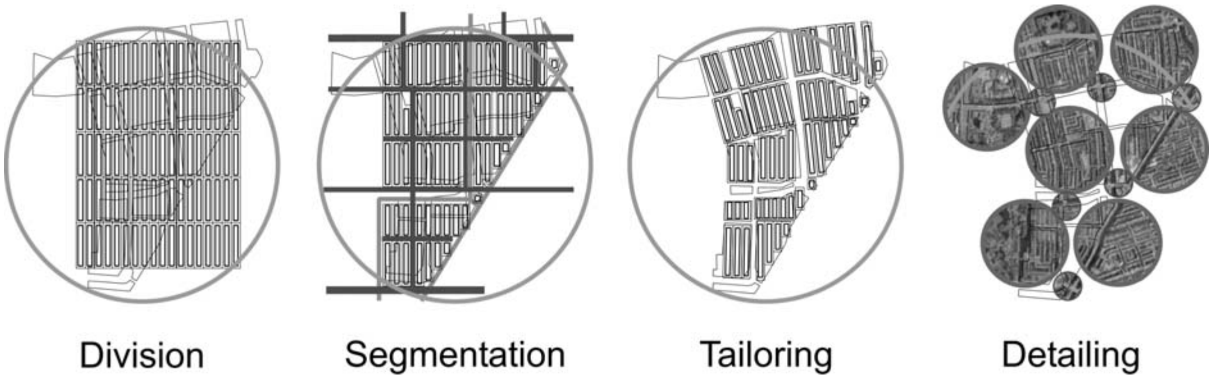

Fig. 105 R=1km Division, segmentation, tailoring and detailing De Baarsjes, Amsterdam[a]

Wider roads of a higher order, such as neighbourhood roads and district roads, may *segment* the district into bounded, more diverse areas. *Tailoring* them according to the existing topography and external boundaries adds some deviations from the original division and segmentation. *De-tailing* them further may connect and separate segments into a recognisable composition, with components and connecting details. The connecting details, then, are mainly crossings. They deserve detailed attention to distinguish the adjacent components (neighbourhoods) for orientation. Roads *between* neighbourhoods, then, may obtain different façades at both sides, while *within* neighbourhoods, opposite façades may become more similar. Division, segmentation, tailoring and detailing may be interpreted either as a design sequence, or as a compositional analysis of an existing district, in order to improve the quality of its image. It is a formal basis for further environmental diversification.

Environmental diversification of components

Further environmental diversification may give each component (such as a neighbourhood) its own identity (difference with the rest and continuity in itself). The difference from other components may contain a different content, form, structure or function, which can be represented by *characteristic*, *crucial* or accidentally *marking* details (see page 102). Differences in content may consist of different values of any variable that was identified in Chapter 3. For futher environmental diversification, you primarily may add content.

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[a] Jong;Ravesloot(1995) *Beeldkwaliteitsplan Stadsdeel 'De Baarsjes' Amsterdam*. (Zoetermeer) assignment Stadsdeel De Baarsjes Amsterdam to MESO.

Content obtaining a form

In the previous sections, the examples of spatial distribution concerned values of 'Land Use', such as net residential 'floor space', 'gross residential urban space' or 'roads'. Land Use may be related to many other variables, but the distribution of their values can be drawn and studied separately. You may draw the distribution of light, furniture, windows, walls, buildings, pedestrians, cars, different types of allotment, horizontally and vertically articulated architecture, high and low places, to name only some of the values that are named in Chapter 3. The result is comparable to the thematic maps in atlases (see *Fig. 26* on page 67). Atlases, however, show a reality, or *probability*, while design studies intend to show *possibilities*.

Quantitative legends

If you distribute one of the values (or any intermediate value) of Chapter 3 as a legend unit in a map, you may give its surface a realistic size, which indicates a possible future.
The legend that is drawn according to the intended quantities, then, may serve as a programme. *Fig. 106* shows a part of a map that was published in the context of a Dutch national plan[a], suggesting zoning quantities. 'struggle for space' are postponed, instead of solved through planning. That solution involves recognising and obeying forces of separation, adhesion, cohesion, and combination, at different levels of scale. There was no other indication of quantities in the plan than this map. If you translate that map in real size dots, and represent the claims that should be added to the existing urban and rural land (see *Fig. 107*), then it seems obvious that such claims cannot be fulfilled easily in the available space. Without quantification of the claimed surfaces, conflicts remain hidden.

Fig. 106 Space demand suggested

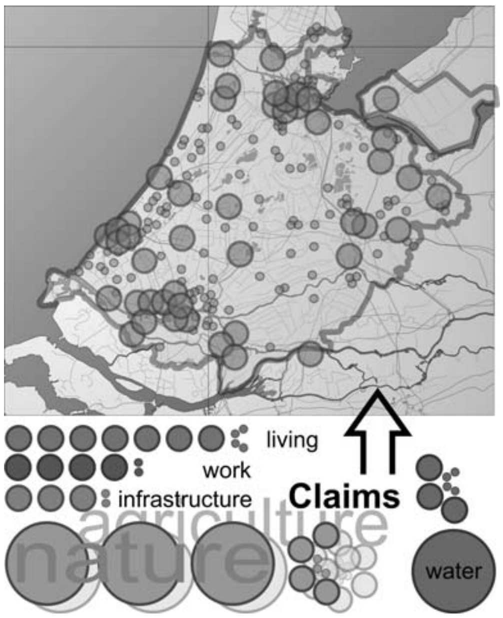


Fig. 107 Claims to add in dots r = {1,3,10km}

[a] VROM(2001) Ruimte maken, ruimte delen - Vijfde Nota over de Ruimtelijke Ordening 2000/2020 (Den Haag) SDU Uitgevers. The plan was never accepted by Parliament since the government changed shortly after its publication.

4.4 Morphogenetic forces anticipating structure

Attraction and repulsion

In physical chemistry, scale sensitive attraction between the different or the equal are named adhesion and cohesion. Repulsive forces may add to form colloids. emulsions or flocculations by aggregation.

This section may anticipate the next chapter concerning structure. Designers are able to develop form and structure separately, but nature mainly alternates the development of form (morphogenesis) and structure (structuring), in a nearly inseparable way. Scale sensitive forces of attraction and repulsion between different or equal values (i.e. legend units for a designer) will re-arrange the intentions of a design by use. An experienced designer will anticipate these natural forces. It may tacitly limit its imagination.

Self-ordering combinations by adhesion, cohesion, resulting in colloids and gels may be reminiscent of physical chemistry, but they show remarkable similarities with spatial morphogenesis at the larger scales.[a]

Cohesion and adhesion

Cohesion and adhesion clearly demonstrate the scale paradox of *Fig. 7* on page 21, at any level of scale. *Cohesion* tends to *accumulate* one value, but at a larger scale it tends to *separate* that value from other values. For *adhesion,* you cannot conclude the opposite. Adhesion tends to *combine*, but at a larger scale, it tends to *disperse* both values. For example, the legend of *Fig. 107* contains a doubtful suggestion that nature and agriculture could be *combined* , in order to save space. *Separating* them would *cost* space. However, if farms should combine nature and agriculture, then they would anyhow divide their area into nature and agriculture at a smaller scale, thereby reducing the surface of both areas as well. *Equal* values may attract each other (*cohesion*), if there are economies of scale. Larger farms may obtain a better efficiency, larger urban areas may support more facilities, and larger natural areas may support more animal species and recreational opportunities (see *Fig. 108*).

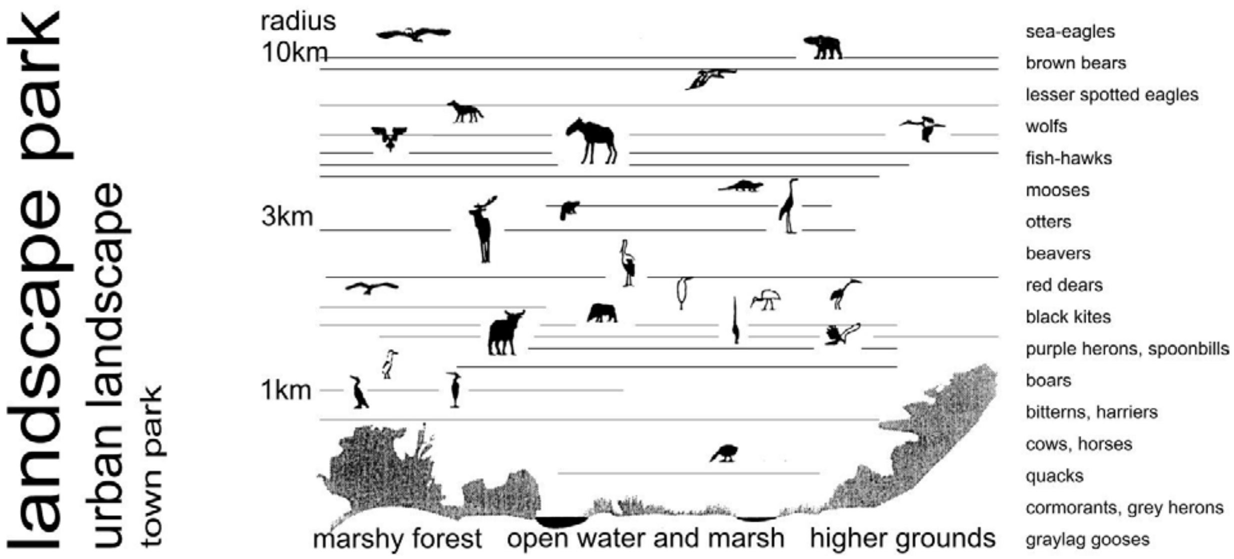
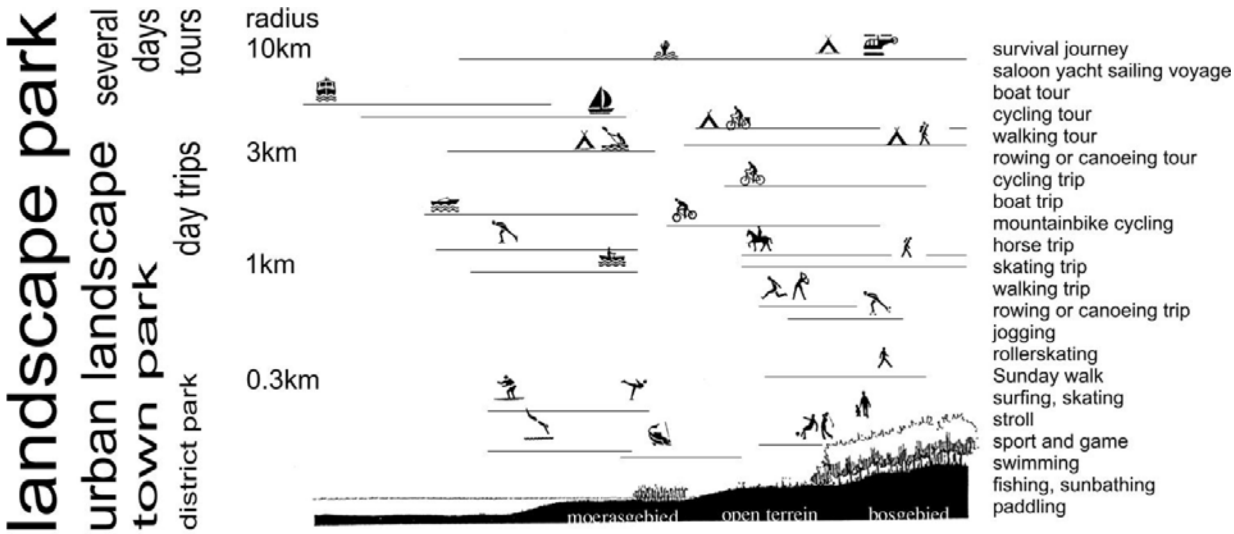


Fig. 108 Ecological advantages of cohesion(economies of scale) and …

a A spatial designer may recognise many concepts in Atkins(1995) *Concepts in Physical Chemistry* (Oxford) Oxford University Press



… recreational opportunities differ per landscape and increase per radius[a]

Adhesion, combination, dispersion

Adhesion and attraction between *different* values may exceed their internal *cohesion*.
For example, parks are positively related to the residential area (adhesion), and consequently, dispersed within that area. At a smaller scale, however, parks still require some coherent, and consequently, accumulated surface themselves (cohesion), in order to obtain the opportunities illustrated in *Fig. 108*.
To balance both forces of adhesion and cohesion, you may design a distribution of parks. In a radius R = {0.3, 1, 3, 10km}, you may propose central neighbourhood~, district~, town~, and conurbation parks with a radius of r = 1/3R = {0.1, 0.3, 1, 3km} respectively (see *Fig. 109*).

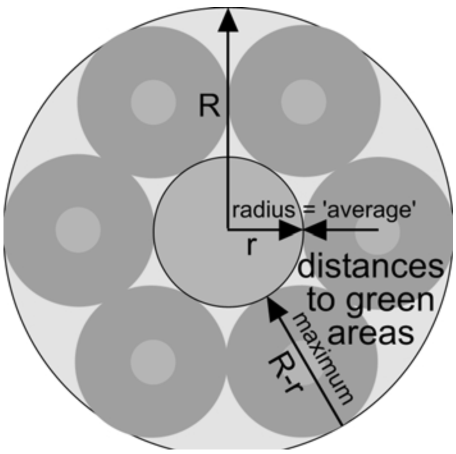


Fig. 109 Standard Green Structure

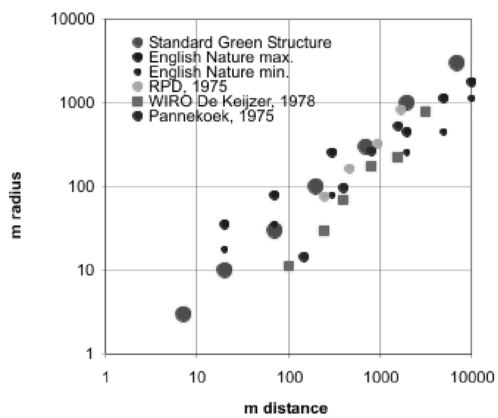


Fig. 110 Some standards for green area

A neighbourhood park r = 100m, then, may require on average 100m walking distance, in order to reach that park. For a district park of r = 300m, that distance would be 300m, for a town park 1km and so on. The average walking distance to a park, then, equals its radius. The maximum walking distance each time measures R-r, or approximately twice the average walking distance. Let us call the hierarchical distribution of parks and smaller greenery in an urban area 'Standard Green Structure'. It comes down to approximately 10% substantial green area for every level of scale that is considered separately.

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[a] Schemes adapted from Hoog;Sijmons(1995) *Groene Hart? Groene Metropool!* (Utrecht) H+N+S

Accepting some suppositions[a], usual standards for parks and greenery fit rather well around this Standard Green Structure (see *Fig. 110*). The deviations of these standards from the Standard Green Structure show their emphasis on either more small parks close to your home, or larger ones at a larger distance. The reality deviates from these standards by eccentric locations and consequently, larger walking distances. The distribution of green space between the built-up area determines, to a large extent, the 'form' of the urban area.

Degrees of attraction

The adhesion of shopping areas and schools to residential areas, which are at a different level of scale, results in similar hierarchic distributions. The increased means of transport, however, make inhabitants choose for the quality of schools and shops at some distance rather than for their presence in the neighbourhood. It decreases their *adhesion* to residential areas. At the other hand, their internal *cohesion* increases by the functional diversification of schools and shops, and their economies of scale. Corner shops and neighbourhood schools, then, disappear from the smaller scale in favour of the larger scales. Jobs show a locational hierarchy that roughly follows the economic cycle of production, *dis*tribution, consumption and *con*tribution. Economies of scale accumulate agricultural and industrial production at coherent agricultural and industrial areas (see *Fig. 98*). Consumption (including home production, café's, restaurants) disperses, and is adhesive to dispersed residential areas. Distribution has its own connections between auctions and shops. *Con*tribution (i.e. collecting and concentrating, the opposite of *dis*persion) of labour (workshops, offices) products (stores) and money (banks), show a reverse hierarchy, with a substantial adhesion in city centres (see Fig. 98). However, many forces of cohesion, adhesion and repulsion influence the balance between accumulation and dispersion. Easy access to information and transport networks facilitates the dispersion of every type of job. However, dispersion without adhesion could break up any existing cohesion. Ideas to incorporate agriculture in urban areas completely, would require at least 1000m^2/inhabitant. It would break up the approximately 300m^2/inhabitant urban area into hamlets.

Repulsion

Cohesion and adhesion are *attractive* forces between similar and different values, respectively. They may be negative, also, resulting in *repulsion* between similar or different values. The space that is required around an individual element (the spot of a dot) is a repulsive force. The more void space individual elements require, the less cohesion a set of similar elements obtains. For example, detached houses may have less 'cohesion' compared to row-houses. The more distance a legend unit has to keep from a different legend unit, the less 'adhesion' they mutually have. For example: industrial areas with environmental zones and adjacent residential areas may have less mutual 'adhesion' than parks and residential areas.

Functional, structural and morphological 'attraction'

The examples above only concern *functional* attraction and repulsion for reasons of clarity. In the beginning of this section, I referred to physical chemistry as a source of the terms 'cohesion' and 'adhesion'. On the one hand, physical chemistry keeps some distance from chemical specifications (*content*), and on the other hand, it keeps them from their *function* in a larger whole (e.g. in biology). It clarifies supra-molecular *structures,* such as colloids, and their processes, such as flocculation and coagulation. It restricts itself to *structural* attractive and repulsive forces. Forces, however, are not observable. They have to be concluded from

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[a] Standards for greenery are often expressed in m^2/inhabitant instead of walking distance. The relation between walking distance and m^2/inhabitant greenery depends upon suppositions about the size of the urban area and the population density of its residential areas. For a village R=1km you may not need town~, conurbation~ and metropolitan parks. The required surface of greenery expressed in m^2/inhabitant then would be smaller for villages than for towns, conurbations or even metropolitan areas. However, the population density of residential areas in a village is mainly lower than of the larger urban areas, providing more green surfaces such as gardens and dispersed public greenery at the lowest levels of scale closer to your home.

observations of developing accumulations and dispersions, and developments of *form*. Describing morphological diversity, then, concerns exclusively studying any stage of such developments between total accumulation and dispersion, avoiding the functional and structural suppositions that will be added in the next chapters.

Appropriate categorisation

Verbal language collects physically different phenomena in words. That categorisation primarily facilitates the description of sequences in time through sentences. This tacitly assumes a linear structure between generalised categories.
For example, the sequence of production, distribution, consumption, contribution may describe an economic cycle. Verbal language cannot facilitate the description of adjacent differences in the different directions of space, and the environments of any point (particularly their form), as easily as a drawing. The spatial realisation of intermediate deliveries, as they are simulated in meso-economic input- output tables is neglected in the generalisations of variables of macro-economic models, but they cause substantial urban traffic-flows.
The legend of a drawing is the vocabulary of design. Its categorisation, however, may be different from what is possible by words. Forcing a designer to express legend units in words may hamper the development of an appropriate design. It is often better to explain the legend units through images. Images as legend units may show differences that are not expressible in words. They may split up similarities that are hidden in words, avoiding their prejudiced categories.
A designer, however, also has to collect physical phenomena of a smaller radius into the legend units of a larger radius. Designing an allotment does not require one to draw all the rooms, with all their furniture. It can be collected in the legend unit ‘building’. Drawing a district does not require one to draw all the buildings; these can be collected in the legend unit ‘built-up area’.

4.5 Diversity of forms

Diversity through distribution

In *Fig. 111* , ten squares are filled with a hundred black dots differently, but at the same overall density. The pictures are tentatively ranked from total accumulation into total dispersion. The extremes of total accumulation and total dispersion seem to show the least *diversity* of form. Any deviation from these extremes increases the morphological diversity. Could you then indicate a maximum somewhere in between? Is the 'shaped' form less diverse than the 'gradient'? How to measure 'diversity' then? I do not pretend to have found a satisfactory measure to rank the diversity values in between. But, I would like to give some considerations that are possibly relevant for the environmental diversification (a *change*) of form, which is the core of design.

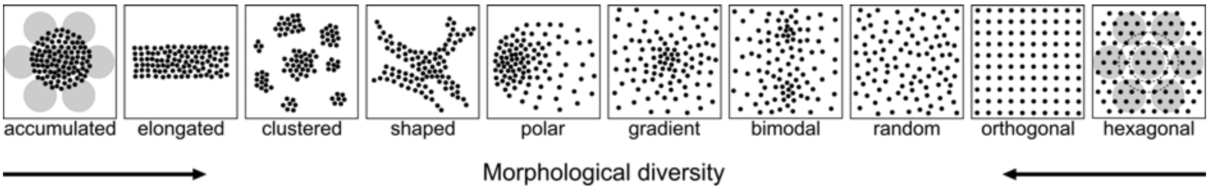

Fig. 111 Increasing and decreasing morphological diversitytentatively related to distribution

Diversity of distances

Fig. 58 on page 100 showed how 'form' can be represented as distances between dots. If you take the environment of each singular dot into account, e.g. the central dot in the 'hexagonal' (most right) scheme of *Fig. 111*, then the 6 nearest neighbours[a] are found at the same distance in 6 equally dispersed directions. In a little larger radius (the drawn inner circle), you will find again 6 dots at the same distance in between the primary directions.
A third larger radius counts 6 dots, this time in line behind the first nearest neighbours.
A fourth larger radius (of the outer circle), counts 12 dots, which introduces new directions. If the pattern is supposed to extend infinitely, then this counts for any other dot. These quantifications are enough to conclude that the environmental diversity in many directions around any dot is low. The same conclusion is valid for any circular *set* of 7 dots.
In the 'orthogonal' scheme (see *Fig. 112*), any dot counts less 'nearest neighbours' at an equal distance compared to the 'hexagonal' scheme (see *Fig. 113*), but its view into different directions counts more dots at larger distances ('the commander can see more soldiers').

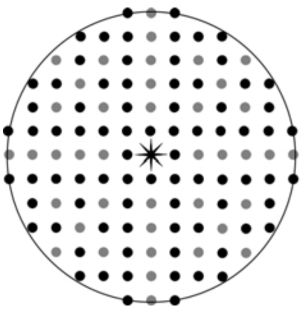

Fig. 112 Orthogonal arrangement: 120 dots, 80 (black) dots visible from the centre

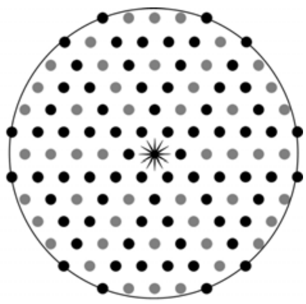

Fig. 113 Hexagonal arrangement: 120 dots, 72 (black) dots visible from the centre

This exercise raises some questions about the hidden suppositions of its conclusions.

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[a] See for example http://geographyfieldwork.com/nearest_neighbour_analysis.htm

Which 'environment'?
Speaking about 'environment' (particularly if it concerns its diversity) hides a supposition about scale. How far does the concept of 'environment' extend? You may choose arbitrary 'elastic' boundaries such as R = {1, 3, 10 …. 300 000m}, but even then, there is still a difference between close by and far away, from the reference point of what you call its 'environment'. The larger the distance, the less it may count as 'environment'. You may reduce the weight of every larger distance from that point, until it reaches a zero value at the chosen boundary. This has been done implicitly in the section above, where I stated 'These countings are enough …'.

Which 'form'?
Form cannot be described fully by absolute distances between elements and their directions. It is an outward approach from the element into the whole. You then observe the form of an environment as if you were one of the dots in a plane yourself, looking from inside outwards. If you look at the images of *Fig. 111* as a whole from outside inwards, then you do not observe 100 times an environment. Rather, you observe patterns with larger regularities, larger shapes with boundaries, and compositions with larger components. You immediately notice regularities as a repetition: as a line (a repeating adjacency), as a shape in contrast with its counter-form (repeated in any direction) or as a composition of shapes. The size of the dots in *Fig. 111* measures 4% of the size of the frames within which they have been drawn. This resolution reduces many possible forms by the resolution of a sketch. Details such as thin lines are neglected. Boundaries are only suggested by contrasting densities, if you take larger sets of dots into account. This reduction is chosen on purpose, in order to avoid mixing too many levels of scale. Any level of scale has its own forms. A microscopic view of human cells does not assist an understanding of the human figure.

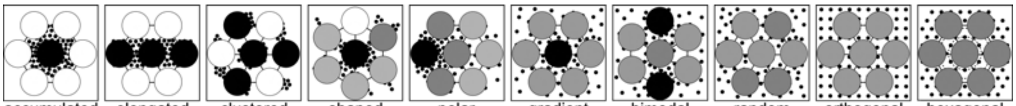
Which 'diversity'?
The morphological diversity of environments that is intended here is not the set of differences *between* the schemes of *Fig. 111*. The set of differences between the schemes is the general variable of average distribution between accumulation and dispersion. The intended diversity is a set of differences *inside* their frame. It is, however, also not the diversity of environments of every separate dot. It is the set of differences between components of a size between the frame and the grain (the size of the smallest dots) of the images. It concerns the *composition* of the schemes (see the grey shaded components drawn in the extremes of *Fig. 111*). It is the diversity between distinguishable *sets* of dots as 'components' of the image, as intended in *Fig. 63* on page 102. There are differences of content, contrast, mixture and proportion between components in a composition. *Fig. 66 – Fig. 68* on page 102 demonstrates that it can be applied at different levels of scale. That diversity, however, depends upon the way you may choose the location, the size and even the shape of the components. It is not easy to standardise that choice, in order to obtain an appropriate measure of environmental diversity.

Which 'components'?
If a child draws a human figure, then you mainly will distinguish six components in its drawing: a head, a body and four limbs. In its most primitive form, it contains two circles and four strokes. Their sizes do not differ much, and there is a central component between the others. Adult paintings and photographs may allow a closer look from different directions, in order to discover many different forms at different levels of scale. To comprehend the composition as a whole, you may take some distance and look through your eyelashes to get an overview, and to discover components that tell the general pictorial story through their mutual differences and relations. Suppose, that the number of filled components that are distinguishable vary between 2-10, and their sizes between ½ – 1/10 of the frame.
The average of that model comes close to the pattern of circles used in *Fig. 63 – Fig. 68* on page 102 – 102, in *Fig. 105* on page 167, and to the grey shades in the extremes of *Fig. 111* on page 173. If you take that hexagonal pattern as a modifiable starting point, then you may

look for the most similar components first. This will allow you to arrive at the lowest possible value of heterogeneity of the composition, before you can evaluate the amount of contrast, mixture and proportion. In the hexagonal extreme of dispersion in *Fig. 111*, all the components are equal. The consequence is, that there is also no contrast, no mixture or proportion to report. It is a zero-point of morphological diversity.

Roughly quantifying morphological diversity

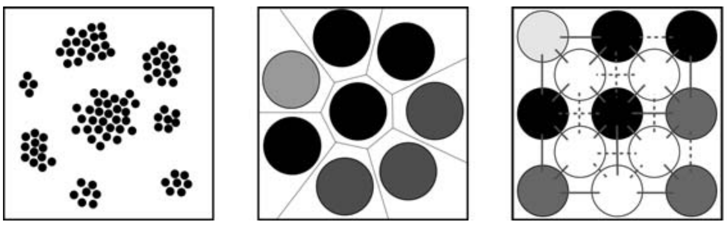
As I stated on page 158, ‘form’ includes the states of distribution of at least two values in space: ‘filled’ and ‘empty’. The components of extreme dispersion are equally filled and empty, but the components of total accumulation are not. One component is filled, the others are not. Consequently, there are 2 colours, with a maximum contrast (say 10), but there are only 6 differences between the components, out of 12 possible ones (the adjacencies in *Fig. 114* most left). If you multiply the intensity of contrast with its number, then you acquire a rough morphological diversity score, as shown in *Fig. 114*. It fits rather well with the preliminary impression of increasing and decreasing diversity in *Fig. 111*, if you adapt the ‘clustered’ image by a slight rotation, in order to distinguish the alternating filled and empty spaces.

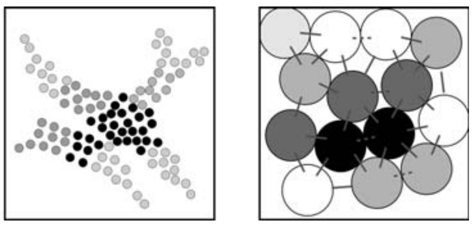


	accumulated	elongated	clustered	shaped	polar	gradient	bimodal	random	orthogonal	hexagonal
#colours x	2	2	2	4	3	2	3	2	1	1
max. contrast x	10	10	10	10	8	6	6	2	1	1
#differences	6/12	8/12	9/12	6/12	10/12	6/12	6/12	7/12	0	0
≈ diversity of form	**10**	**13**	**15**	**20**	**20**	**6**	**6**	**2**	**0**	**0**
			adapted							

Fig. 114 Roughly quantifying form diversity of form by reduction into 6 components

The simple hexagonal template has a clear centre and a clear periphery. It distinguishes 6 potential ‘radial’ differences of the central component with the peripheral ones and 6 ‘tangential’ differences of the peripheral components mutually.
An interpretation, restricted to a regular hexagonal template may benefit some forms and harm others. The only freedom to get (subjectively) a better fit is to rotate it (as done for ‘shaped’ and ‘bimodal’), to adapt reality into a prototypical one (as done for ‘clustered’) or to increase the resolution. At this resolution, however, the interpretation of the images ‘clustered’ and ‘shaped’ are unsatisfactory.





#colours x		3	3		5
max. contrast x		8	10		10
#differences		8/14	21/32		24/28
≈ diversity of form		**14**	**20**		**43**

Fig. 115 8 and topological 8+ components ‘clustered’

Fig. 116 10+ components ‘shaped’

The resolution of sampling
The hexagonal template does not cover the obvious 8 clusters, and the ‘shape’ image is reduced into an unrecognisable scheme. The ‘clustered’ image would fit much better in a template of 8 components. Such a slightly higher resolution increases the number of colours (you now can distinguish more than 10, 5 or 0 dots covered in different shades of grey instead of less and more than 5), but it decreases the contrast (still neglecting the obviously empty spaces) and the number of differences (see *Fig. 115*). The resulting score, then, is 14. Releasing the actual locations topologically allows one to add empty components. It would result in a score of 20 (see *Fig. 115*).

The location of samples
To do more justice to the ‘shaped’ image, you may increase the resolution into 10 filled components, release the template and add as many empty ones as you can (see *Fig. 116*). To locate and colour the components, you may start counting dots at the periphery. Give any successive set of 10 dots a colour, ranked according to their density. Replace these sets by components with this colour. The ‘shaped’ image of *Fig. 111* ,then, seems to be the most diverse. Another shape, however, would produce a different value. Slightly vaguer boundaries mainly would produce the same result. At a higher resolution, however, the ‘gradient’ images, (including ‘polar’ and ‘bimodal’ without clear boundaries at all) would measure even more colours and differences than any ‘shaped’ image. A very low resolution at the level of dots, however, would remove the recognition of density-transitions of sets that are required to recognise forms and shapes. Anyhow, the resolution influences the ranking. The choice of sample locations remains a subjective element. There may be many ways to improve or refine this rough approximation of morphological diversity (including directions, weighting distances or just neglecting them in a topological way and so on), but I doubt whether it is necessary in the context of environmental *diversification*. A *change* of diversity primarily requires the comparison of 2 forms, only in a way that depends on the purpose.

Diversity of form facilitates different functions
The intention to reduce or add diversity may be, to make your design more recognisable (less chaotic) or more surprising (less boring), in the balance that is depicted in *Fig. 64* on page 102. That is functional, but form conditions more functions than the quality of the image. The adaptation of a utensil to your hand, of clothes or furniture to your body, or a house to the requirements of your family, all condition their function and your use. Even the form of a conurbation facilitates or hampers (‘conditions’) your contacts, your travel time, and its function. If it has a high density in its centre and lower densities in its periphery as the ‘gradient’ image of *Fig. 111*, then it saves time in its centre, but it offers space in its outskirts. Diversity offers freedom of choice. Family people with children will prefer more space to live, and consumers and careerists will prefer more time to act outdoors. This functional diversification may follow the form of the conurbation, but in the long term, the form may be adapted to the function through planning and design at different levels of scale.

Structure between form and function in biology
In biology, the formation of enclosures conditions the operation and performance of cells. The cell wall is a primary enclosure$_1$. It separates an interior from the outside world, thereby allowing processes of a higher order (lower entropy). Embryology describes the beginning of any vertebrate organism as a cell cleaving repeatedly until an accumulation of cells, a ‘morula’, has been formed, which is large enough to produce an enclosure$_2$ of a second order, a ‘blastula’ (see *Fig. 117*). The second order interior$_2$ is surrounded by cells, allowing the inner cells to operate differently from the outer cells. The outer cells will develop into skin and nervous tissues (ectoderm), the inner cells into blood, bones and muscular tissues. Operational conditions, then, prepare the performance of functions.

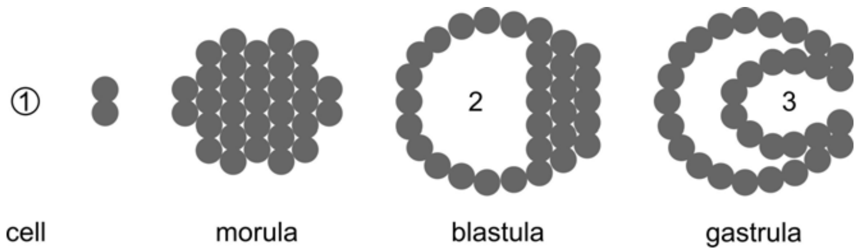


Fig. 117 Gastrulation producing interiors of a second and third order R=10-30μm

The next stage of development shows an invagination$_3$. It will develop into the inner surface of the digestive and respiratory system, as the liver and pancreas (endoderm). It creates a third order of interior$_3$, a gastrula, with a selective access (mouth, nose) into the outside world. New operational conditions prepare digestive and respiratory functions. These functions, then, are possible through a structure of separations and connections, and that structure has become possible by a specific distribution of cells (form). In its further development, the bilateral symmetry about an axis (form) provides the body with a polarity (structure), ending in a head with its mouth, nose and sensory systems, which is selectively open to the outside world, and a dorso-ventral polarity between the front and backside of the body. Bilateral (two polarities), radial (one polarity) and spherical (no polarity) symmetries distinguish different taxa of the animal kingdom. Structure (enclosure, polarity) is not caused (made probable), but conditioned (made possible) by form: its local adjacencies in lines and surfaces.

Structure between form and function in design

In a radius of R = {30, 100m} , a kind of blastula and gastrula is recognisable in old defence systems (see *Fig. 118*) or closed building blocks with invaginating courts (see *Fig. 119*).

Fig. 118 Muiderslot R=100m[a]

Fig. 119 Oudemanhuispoort, Amsterdam R=100m[a]

Structure has a form. It supposes a distribution in space within a larger form, but it supposes more than enclosure or symmetry. A blastula is not operational if the enclosing cells do not have a firm, mutual coherence. Structure, in a more general sense, is any set of connections and separations. If locations are separated by distance, then they may be connected by roads. If locations are connected through adjacency, then they can be separated by walls. Structure changes the probabilities of form. It may stabilise improbable forms. If the structure of a building fails, then its improbable vertical distribution of building materials will return to its more probable horizontal dispersal of a ruin.

[a] Google Earth(2012)

4.6 Diversification of form

A change of distribution and quantity

Clouds continuously change their form, through their distribution of drops in the air. But, they also shrink or extend in different directions. Some drops evaporate, and others appear through condensation, or fall down as rain. A change of quantity necessarily changes the distribution. A change of quantity, thus, is part of the diversification of form. But, the force responsible for that part is different. In clouds, the *quantity* changes through a balance between molecular movement (temperature) and the concentration of water molecules (humidity). The other part of distribution changes through the wind and its local deviations.
In organisms, these forces are the cleaving and the movement of cells.
In architecture they are the addition of building materials and their positioning.

Which distribution and quantity changes?

You may describe the *change* of any cloud in a strict sequence of words (sentence), or as a sequence of variables and operators (formula), but the particular cloud itself, the subject of change, its state of distribution, the 'image'. has to be stored in an xyz-database and *drawn*. It requires a different kind of understanding. This way of understanding is also required for other kinds of difference than change and a sequence of repeating changes (behaviour). What is the initial state of diversity in the sky *from which* you can successively distinguish its changes? What is the origin of that diversity, the cohesion and separation of singular clouds you observe, instead of a homogeneous fog? There is no initial state. Παντα ρει, anything changes. Your image is an unrealistic still. The distribution of clouds in the sky is a consequence of their history. The mechanism of selection and regulation of particles is dispersed and changing. You may point to the heterogeneous surface of the Earth, where the wet parts produce clouds as soon as the sun shines (determined by other clouds, other histories). There, the water evaporates, moisture ascends as long as the surrounding air is colder. This, however, replaces the question. The surface of the Earth itself changes in the long term, and the local evaporation changes through conditions caused by other clouds in the short term.

The origin of a cloud

The pressure, and mainly the temperature in the atmosphere, decrease by altitude. Ascending moisture extends, cools off and starts to condensate as soon as it reaches the condensation level (at a temperature called 'dew-point', which is related to %humidity). At that altitude, a cumulus cloud grows like a cauliflower with a flat bottom.

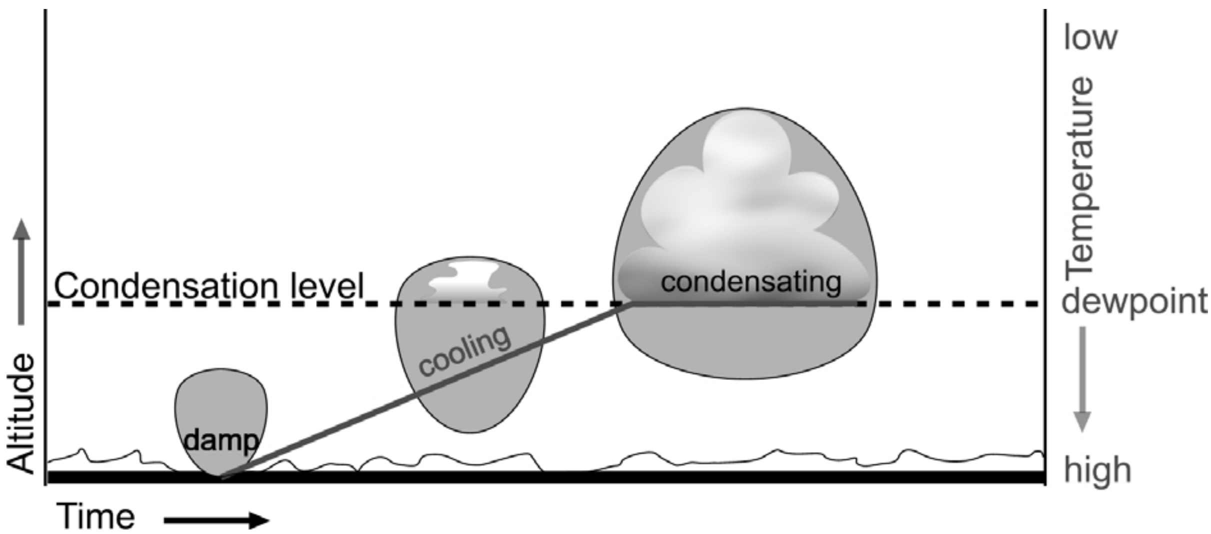


Fig. 120 The origin of a cloud

This flat bottom indicates the point where condensation begins, the dew-point. Losing its coldest parts through condensation, the remaining reheated moisture ascends further, until its temperature equals that of the surrounding air. An occasional wind, its temperature, and moistness, immediately starts to move and change the clouds, until they appear above you. This raises the question: where does that diversity come from?

Time scales of change

If you point to the diversity of the Earth's surface to clarify the diversity of clouds, then you refer to a slower process, to a different time scale of change, repeating the same questions. If the Big Bang initiated a history of dispersion of matter, then the question where its diversity comes from remains. Was it already hidden in the inconceivable accumulation of matter 'before' the Big Bang? *Fig. 111* suggests total accumulation as an example of low diversity. There is, however, no sense to wait for an answer, if it is your task as a designer to change the distributions of matter, which is functional at the limited time scale of the use itself. It is enough to realise that the main trend is dispersion with local accumulations through gravity, which remains in an overall expansive movement. The main trend is increasing thermo-dynamical disorder, which is entropy with local exceptions through enclosures. The actual state of distribution is your initial state as a designer. If it is more stable than clouds, than it will select and regulate your possibilities of change, through design. Solids change their form slower than gases; buildings are less mobile than people; cell membranes are more stable than the water they repel at both sides.
Less changing components (structure) select and regulate the mobile ones.

Selection and regulation

A mechanism operates through combinations of stability and change. The cells of a blastula must join firmly together as a stable skin, in order to enclose the vulnerable, still moving, and changing cells inside. The external structure enables their own diversification into blood, muscles and bones, to develop their own selectors and regulators, and ever more restricted movements and changes at a smaller scale. Selectors and regulators separate and connect in different directions (see *Fig. 8* on page 29). If the connections and separations (structure) are stable, than your blood can flow in the right direction through your arteries, and your impressions can reach your muscles to perform the right action through the nervous system. A stable environment seems to produce more diversity (form), complexity (structure) and specialisation (function), than in a unpredictably changing environment. In ecosystems, you may recognise an even more general relation between difference and continuity on one side, and equality and change on the other side (see *Fig. 10* on page 36). In this scheme, equality is the absolute ('zero') value of difference, and stability as a zero-value of change.[a] Equality, thus, is a special case of difference, and stability of change. This is very convincing for designers, but it is counterintuitive using a verbal language.[b]

The reduction of impressions by verbal language

Words are supposed to be generalisations of special cases, expressing some of their equalities, not the other way around. Words primarily represent equalities, which are subsequently specified (diversified) by adjectives, attributive adjuncts or further specifying sentences. Verbal language, then, starts at the largest sets, in order to arrive at smaller overlaps and subsets. This is a primarily deductive way of distinction. The diversity of your inductive impressions is reduced to traditional categories (words) beforehand, if you attempt to express them in words. The reconstruction of any diversity that way fundamentally must overlook diversities that may be expressed in images. It may be the role of art to become aware of other categorisations.[c]

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[a] Jong(2007) *Connecting is easy, separating is difficult* **IN** Jong;Dekker;Posthoorn, *Landscape ecology in the Dutch context: nature, town and infrastructure* (Zeist) KNNV-uitgeverij

[b] Sloep(1983) *Patronen in het denken over vegetaties. Een kritische beschouwing over de relatietheorie* (Groningen) Stichting Drukkerij C. Regenboog. a mathematically oriented thesis rejecting Van Leeuwens theory

[c] Jong(2008) *Art's task for science* (The Hague) Royal Academy of Visual Arts Opening course Art Science 2008-2009

The direction of distribution

The Earth meets its atmosphere at a horizontal boundary between solids and gases. Vertical elevations (mountains, trees, buildings) are improbable exceptions, which are equalised in time through erosion. Building (vertical dispersion of solids) is difficult, destroying (horizontal dispersion) is easy. Gravity operates as a selector, by concentrating (separating) vertically and de-concentrating (connecting) horizontally. Building a space station requires different statics than architecture. The direction sensitivity of selectors in *Fig. 9* concerns dynamics. They demonstrate a perpendicularity paradox which is also valid for statics. A dynamic connection in 1, 2, 3, 4, 5 directions supposes separation in 5, 4, 3, 2, and 1 directions, and the other way around. A wall may separate in 2 directions, if it is firmly connected in 4 directions. Gravity concentrates vertically, at the cost of horizontal de-concentration. A column, and de-concentrating floors against gravity, must concentrate their material horizontally (resist strain).

Design as distribution of content

Spatial design supposes a change of probable distributions of a content into useful possible distributions. It requires some insight in horizontal (maps, floor plans) and vertical (cross sections) distributions. Designing horizontal distributions requires *concentrating* within a natural trend into dispersion, while vertical distributions require *de-concentrating* in a probable accumulation by gravity.
In *Fig. 121* , a very common building allotment is redrawn in units of floor space per inhabitant. In the Netherlands, there is approximately 30m^2/inhabitant residential floor space available at average, which is represented here as circular dots of R = 3m. A total de-concentration would fill the available surface of 60 x 100m nearly completely. Necessary space for public access and parking reduces this surface at its boundaries. Visual access at two sides of a dwelling unit (at least 2 dots) is a supposed requirement that regulates distribution. The concentration of dwellings at the boundaries encloses an outdoor space. Enclosing an outdoor space is a first step of morphological diversification at this level of scale, which polarises the dwelling into a public front and a private back.

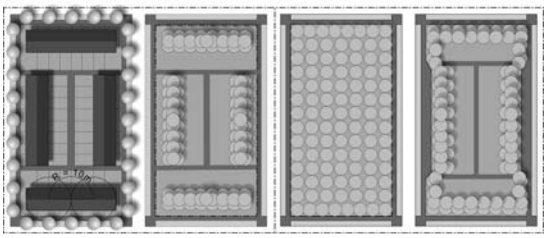

Fig. 121 Distributions of floor space for 100 inhabitants in 30m^2 circles R = 3m

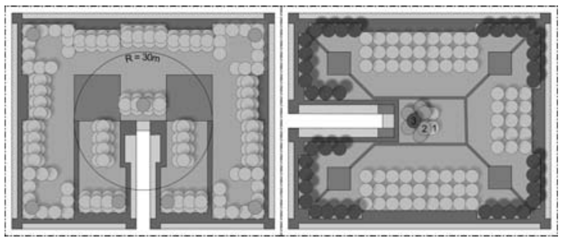

Fig. 122 Redistributions for 200 inhabitants at equal density (darker colours ~ more floors)

Fig. 122 shows a second step, creating more values between public access and private enclosure, and saving space for public access by invagination at one side. It requires a lager surface, but polarises the allotment as a whole, from 'open' into 'closed'. The representation of quantities in dots is an intermediary between the text of a quantitative programme and a final design, which disperses these quantities in space. Further refining the design, dividing any R = 3m (30m^2) dot into 10 even smaller R = 1m (3m^2) dots, and so on, is an effort of architectural elaboration and detailing. This representation clarifies design as a distribution in a technical and social context, selecting the possible connections and separations as structure. The vertical distribution requires even further structural diversification.

Redistribution

In 2008 I was asked to advise the Chinese conurbation of GuiYang (3 million inhabitants) in the province Guizhou concerning an North-Eastern sustainable extension where the river Nanming turns into the North for approximately 200 000 inhabitants. The existing master plan proposed a dispersion of residential towers in a nominal radius of 1km. A rough analysis of the drawings into nearly 2000 stacked dots r=30m (3000m^2, say 100 people) indicated a capacity of approximately 6 km^2 floor space (see *Fig. 123*).

R=1km

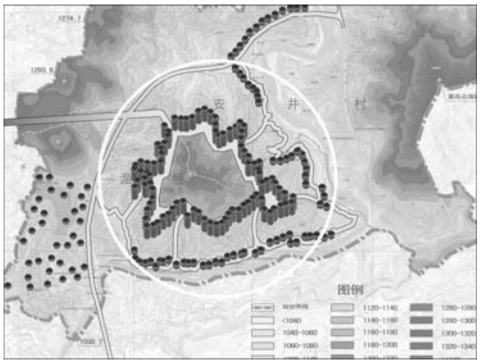

Fig. 123 Analysis of the Master-plan

Fig. 124 Redistribution around the central hill

A simple redistribution of dots, concentrated on the altitude line of 1160m would produce a 'Chinese wall' on the central hill (1260m high) as a crown on its head. The remaining capacity could be found in low rise buildings along the river. As a sketch r/R=3%, it shows a design that can be characterised as distribution of quantities in space. The flexibility of this design can be expressed in a distance of interpretation of the sketch. You then may state that every dot may be interpreted in a radius of 100m around its centre (dot tolerance). The R=300m concentration of these quantities in *Fig. 124* reduces the length of landscape fragmenting roads. It reduces the paved surface, the length of cables and pipes. It supports public transport, and at its stops, it provides new opportunities for facilities. It emphasises the existing topography of altitude lines saving the different landscape views of the majority of the inhabitants. They will defend the open spaces in the future making the plan sustainable. At the altitude line of 1160m a terrace of 80m wide must be cut out of the mountain, giving space for high rise building, parking space and a strictly horizontal access road to stimulate cycling and walking, supporting the elderly. The outer 30m delivers the surface for building. Multiplied by 50 stories, that is 5km^2 floor space, it covers nearly the entire capacity of the master plan (6km^2). The mountain has got a 'crown' hiding its forest top from outside, but daily seen by 160 000 people as a mysterious centre of their borough. On the other side they are awarded by a view over a landscape, unspoiled by high rise buildings. A second strictly horizontal road along the altitude line of 1040m produces the remaining 1km^2 floor space with a view on the river. The natural area of the hill top should be connected by corridors with its roots and the river in favour of concentrated water runoffs and ecological exchange. The Northern part of the 'wall', however, is located on an unattractive North slope attacked by cold Northern winds, probably diversifying the price of dwellings. The Eastern access road coming from the core of a metropolis enters strange emptiness suddenly followed by a complete city on a hill.

The Diversification of form

The possible diversity of form between the simplest cases of total accumulation and total dispersion is inconceivably large. For example, if a programme of 47% built-up, 24% pavement and 29% green has to be divided over 17 locations, then there are more than 3 million possibilities to do so (see *Fig. 125*). Our imaginations restrict ourselves to the known distributions and many kinds of supposed selections and regulations. But ,you may obtain some inspiration by accident that extends your imagination. *Fig. 125* is a screen copy from a computer programme[a] , which is used to explore the number of possibilities. It produces six new alternatives by pressing a button.

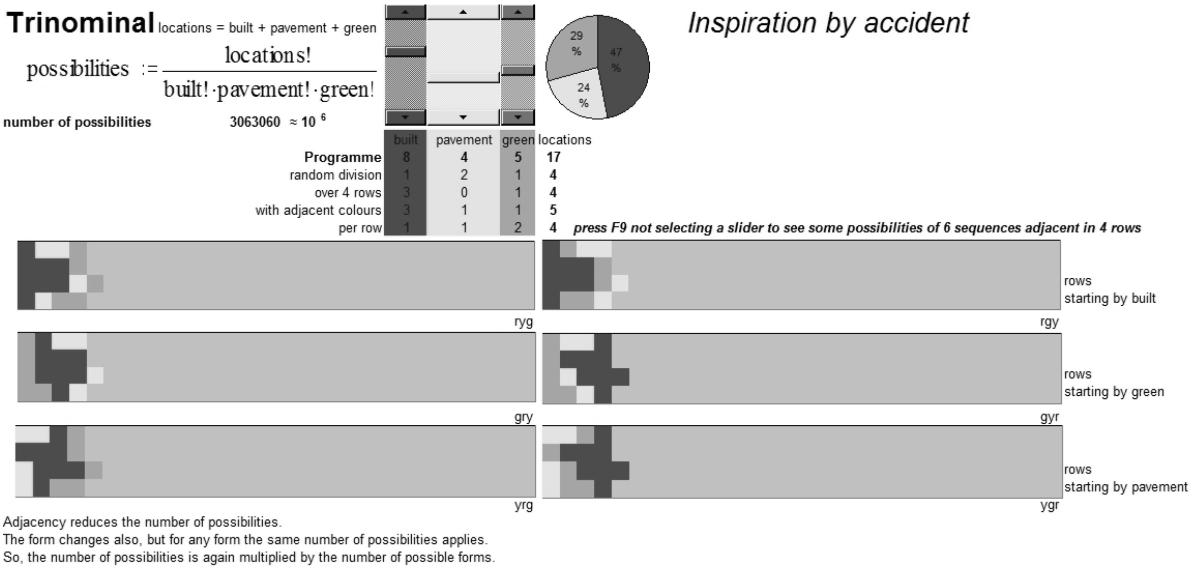

Fig. 125 Some examples of three quantified colours distributed of over 17 locations[a]

Many of the random distributions may be useless, but if you are unaware of sufficient alternatives, you may overlook possibilities. Your suppositions about many kinds of structural and functional restrictions hamper your ability to study the possibilities of form as it is. Culture is the set of shared suppositions in a community.
It is difficult to discover your silent suppositions, if they are commonly shared in a culture.
It is difficult to explain to a fish what water is, unless it is pulled out of its natural environment. Creativity is leaving out at least one of these common suppositions. This chapter attempted to get an overview of *all* possible forms, without other suppositions. Observing biological processes of morphological *diversification*, however, forced me to take selecting and regulating structures into account. They have a distribution in space, with its own diversity. That distribution selects and regulates the other components, their composition, their form and the possibilities of their use. This anticipated the subject of the next chapters.

[a] Downloadable from http://team.bk.tudelft.nl/Publications/XLS/07Legends.xls .

5 Diversifying structure

5.1 Structure

A stabilising set of connections and separations

In this thesis, 'the way parts form a whole' is not a sufficient definition of 'structure'. 'Composition' may be an external way that parts can be *perceived* as a whole, but it is different from an internal structure that actually stabilises the form of the whole. Any form would be as unstable as a cloud, without connections and separations keeping them in form. Connections and separations are active (often hidden) components, or details, of the form themselves. They are different from the passive adjacencies and distances that are observable between a form's apparent components. These may be *called* 'connections' and 'separations', in order to express a visual impression. But, they do not actually connect or separate. Structural elements even may compensate them. Neighbours can be divided by separations; distances can be bridged by connections. In this thesis, 'structure' is 'the set of stabilising connections and separations', and its result is 'coherence'.

Structure makes a form stable and operational

Connections and separations may stabilise a form, but (supported by gravity) they also selectively allow movements in their environment. Stable, solid parts select and regulate more changing or moving parts, their degrees of freedom, and their amount or velocity. The composition of a house, with its stable constructive elements (roof, floors, walls, cables, pipes, foundation, rooms), includes doors, windows, a household, its moving inhabitants, their moveable furniture, circulating air and other mobile properties. The mobile components would not function without any stability in their environment. Structure supposes differences of change. Anything changes, but not everything changes at the same pace. There are both direct and indirect material separations and connections, which supposes a range between solid matter and air. There are also immaterial separations and connections that stabilise material form. Bans and duties regulate human activities through laws and habits.
What structure *does* (connecting, separating, enclosing, selecting and regulating) is summarised in the term 'operation'. Operation is something else than 'performance' (serving a human function).[a] Operation makes a performance possible. A mechanism must be operational before you can use it. Any biological function supposes a structure, and consequently, a form (see *Fig. 126*).

[a] A distinction made by Tzonis(1992) *Huts Ships and Bottleracks Design by Analogy for Architects* **IN** Cross; Dorst;Roozenburg**,** *Research in design thinking* (Delft) Faculty of Industrial Design Delft University of Technology the Netherlands Proceedings of a workshop meeting

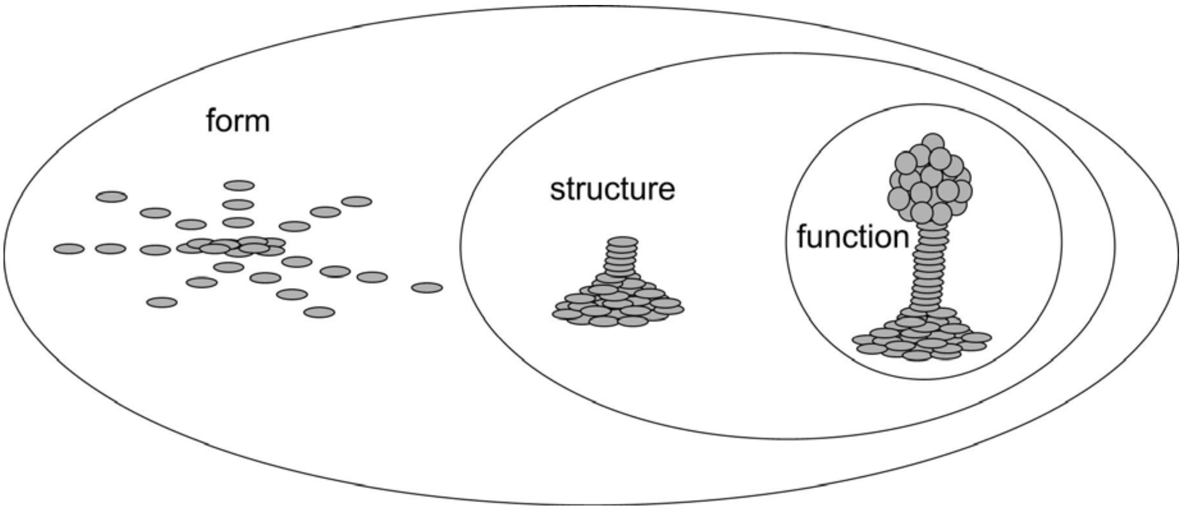

Fig. 126 The sequence of form, structure, function in the development of Dictyostelium discoideum R = 100 μm (the approximately 100 000 cells are depicted too large)

The evolutionary process from singular cells into an organism is currently repeated in the epigenesis of the slime mould Dictyostelium discoideum. It shows a process of concentration, structuring and functioning in a conditional sequence. This sequence, however, is not necessarily the sequence of design.

Variable coherence

Biological connections and separations may be more 'elastic' than human buildings. They move a little with their mobile, fluid or flowing environment, but they remain coherent. From temporary deformations, they mainly come back into their original form (resilience).
Biological structures show less differences between stable and mobile parts than buildings. Moreover, they may show a gradual transition in space between more and less degrees of freedom, and less and more coherence (see *Fig. 127*). For example, mucous membranes show a transition from coherent into free movement through secreted mucus; sticky, thick fluid trapping pathogens.

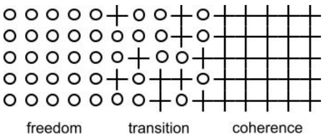

Fig. 127 Variable coherence

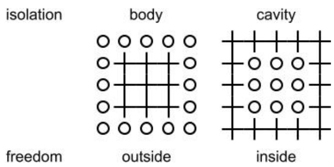

Fig. 128 Isolation

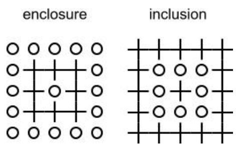

Fig. 129 Enclosure

A radially symmetric sequence of coherence may isolate bodies or cavities (see *Fig. 128*). Repeating this sequence may produce enclosures and inclusions (see *Fig. 129*).

Static and dynamic connections and separations

The terms 'connection' and 'separation' are ambiguous (see *Fig. 71* on page 105, repeated below). A wall separates in a different way than a column. A tube and a rope (or a stress resisting cable or stave) connect differently. In dynamics (see *Fig. 130*) and statics (see *Fig. 131*), 'connection' (convergent arrows) and 'separation' (divergent arrows) obtain a different meaning.
Separation requires a kind of connection that is perpendicular to the direction of separation. The other way around, connection requires a kind of separation in perpendicular directions. I will refer to this phenomenon as the 'direction paradox' (see page 28). A wall separates in two directions, but the separation requires a simultaneous connection in other directions.

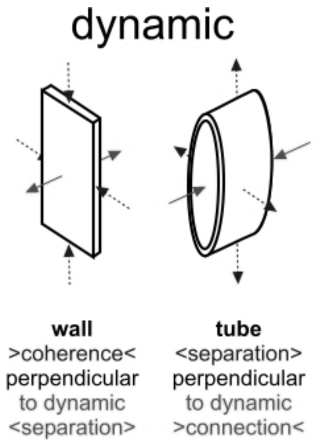

Fig. 130 Dynamic connection and separation

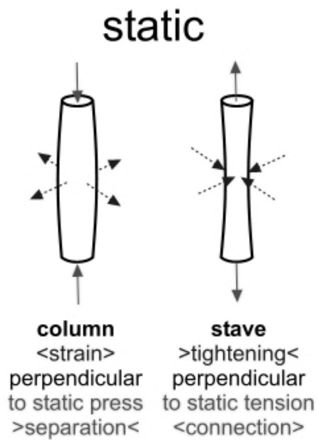

Fig. 131 Static separation and connection

Any operation (continuous arrow) requires secondary operations (dashed arrows) into the other directions. In *Fig. 130* and *Fig. 131*, the operation of the element (the resistance) is drawn, not the opposite (potential) movements it resists (which may be disturbing reading the images). A column resists the potential collapse of a floor, counteracting the force of its weight. Any operation resists movements or potential movements (forces) in some direction(s), in favour of movements in the other direction(s). In the gravity field on the Earth's surface, such operations may prevent natural, probable movements of vertical concentration (collapse) and horizontal de-concentration. Structure, thus, makes 'improbable' states of dispersion possible. Improbable possibilities are the core of design. Designers primarily draw connections and separations, even if they want to create possibilities in their counter-form.

Selectors and regulators

Devices that combine separation and connection in different directions, such as depicted in *Fig. 130* and *Fig. 131* , are selectors. They select the *directions* of resisted or allowed (potential) movement. The selectors of *Fig. 130* and *Fig. 131* are symmetrical in 3D, but there are also less symmetric selectors, such as a deck, a gutter or a bowl (see *Fig. 8* on page 29). What we have called 'enclosure' in the previous chapter, is essentially a bowl with a primarily radial symmetry. An urban square has the structure of a bowl. A street is a kind of gutter. The open land is a deck, leaving the highest degree of freedom at a gravity surface. If you accept time as a seventh possible direction, then a tap separates, but sometimes it connects if it is 'open'. Bridges, doors and transistors are essentially taps. If a tap regulates a flow between open and closed, you may call it a 'regulator', which may be a special kind of selector.

Conditional selectors

A tab is – in a more general sense – a 'conditional selector' (see *Fig. 9* on page 29). Its 'condition' is time. A sieve may select on size: open for small particles, but closed for large objects. Pedestrian or cycle paths may be closed for cars by stakes. Thus, the sieve is a conditional selector with size as its condition, but you may imagine other conditions for the selection by a sieve. For example, a cell membrane may be selected based on its chemical characteristics. A window is a sieve open for light, but if it can be opened for other movements, then it is also a tap. Legal regulations are concerned as non-physical, but their impact may be physical. They may operate as a tap or a sieve, structuring space and movement. Linguistic 'if…then'-constructions operate as a tap or a sieve. Zoning plans contain many of these conditional constructions, as a crucial legal part of their design.

Variable enclosures
The absolute value (zero point) of enclosure or seclusion as a variable may be total openness, because there is no absolute impenetrable 'seclusion'. You always can add more isolating boundaries, but not always less. Isolation is relative. An enclosure may be separated by a semi-permeable or perforated wall. Thus, the perforations , such as windows and doors (sieves and taps), do not make the enclosure 'more open', but 'less closed'.

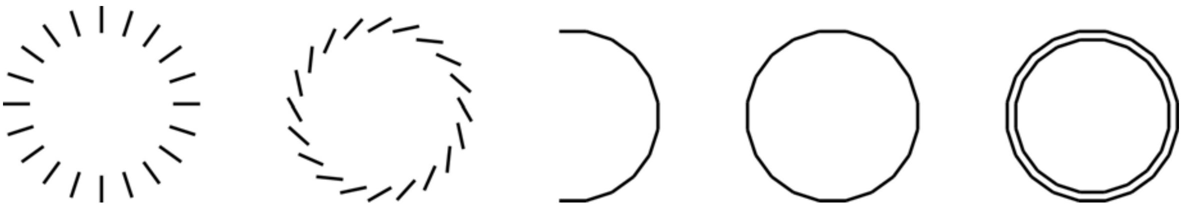

Fig. 132 Enclosure from open into more closed

Eco-device
An enclosure combining walls, sieves and tabs is known as an 'eco-device'[a] (see *Fig. 133*). An eco-device distinguishes two inward and two outward operations. The walls and sieves 'resist' inward movements or 'retain' outward movements. Openings, sieves or taps allow regulated 'input' and 'output'. 'Systems' distinguish a boundary and an input and an output, but the concept of an eco-device makes designers aware of different operations of the boundary. A boundary is usually concerned with having symmetrical surfaces at both sides, but the opposite operations may require some asymmetry.

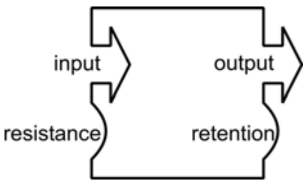

Fig. 133 Eco-device

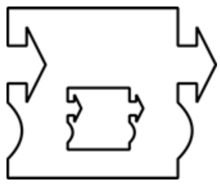

Fig. 134 Enclosing and enclosed eco-device

Different structures at different levels of scale
An enclosure may be embedded in a larger one (see *Fig. 134*). Then, it will operate differently with a different input, output, resistance and retention. At every separate level of scale, you may observe different impacts of connections and separations that select and regulate different processes. Outer structures 'protect' inner structures. From a radius of R = 30m onwards to the larger levels of scale, the impact of static connections and separations fades (see *Fig. 121* and *Fig. 122*). The vertical resistance against gravity, then, is dominated by the larger horizontal operations. At a larger level of scale, the selectors are mainly dynamic. Many selectors are visible as linear elements, such as landscape boundaries, waterways and roads. But, smaller differences of soil select plants, the availability of air and water selects species, the access of sunlight selects activities.

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[a] Leeuwen(1979)Ekologie I(Delft)THD 3429

A sequence of selective operations

If you go out, you will meet many selectors. You put your *coat* on; you leave your *house* through a *door*, *closing* its *lock* properly with a *key*; you put up an *umbrella* or you put on your *sunglasses* walking along your garden *path* into the *street*; you *unlock* and *open* your *car,* and so on. Any selector resists or mitigates the impact of natural phenomena of a larger scale, such as sun, wind, and water, potential threats, and distances that should be bridged. Moreover, there are many implicit selectors that protect you from silent threats, such as dikes, insurance, health care, and legal regulations, which may be executed by police or army, traffic lights and regulations. They must be included, or may be supposed, in any spatial design. The potential diversity of structure, however, is not as much elaborated and utilised in the human environment as you may observe in living systems, and less so in mechanical engineering[a].

[a] Rodenacker(1970) *Methodisches Konstruieren* (Berlin / Heidelberg / New York) Springer-Verlag

5.2 Polarities until 1km

Between ‘open’ and ‘closed’

The connections and separations introduced in the previous section are crucial in design. Their operations often result in a spatial polarity P, from ‘closed’ to ‘open’. Such polarities offer a global concept of ‘structure’, in order to be distinguished by a radius r, of their operation as P_r. At any level of scale you can observe locations that are open on one side and closed on the other side. *Fig. 117* on page 177 shows an embryo that is primarily developing a $P_{30\mu m}$ through gastrulation. *Fig. 126* on page 184 shows non-polarised cells developing a $P_{100\mu m}$, with a globe on top, opening to disperse its seeds. Plants, animals, humans, furniture (P_{1m}), rooms (P_{3m}), buildings (P_{10m}) and allotments (P_{30m}) show a back and a front that cannot be turned backwards or upside down without becoming inoperable. Architecture, urban and technical design innocently determine many polarities. If you use them to analyse the potentials of a location by drawing, and modify them into a global concept, then your very first ideas can be discussed. These drawings may serve as a starting point for further detailing your ideas into more specific connections, separations, selectors and regulators through design. You may diversify them further into new kinds of structures, at different levels of scale. This section aims to clarify existing polarities at any level of scale, and to make them operational for design.

The radius of polarisation

In a radius of R = 1m, you share a polarity (see *Fig. 135*) from back to front, with many animals. The openings of your eyes and nose are close to your mouth, which is also the input location of your gastrointestinal tract and the location of your taste. This polarity of your body suits the direction of your forward movement looking for food, opportunities, new experiences or danger. This primary polarity, then, integrates your sensoric and motoric operations.

Fig. 135 P_{1m}

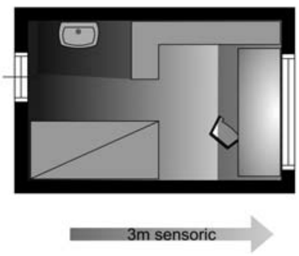


Fig. 136 P_{3m}(sensoric)

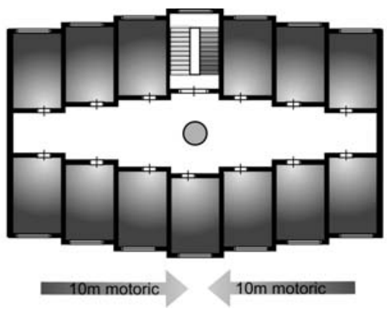


Fig. 137 P_{10m} (motoric)

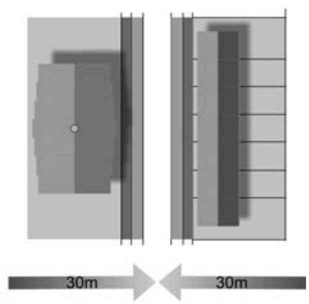


Fig. 138 P_{30m} (private-public)

A second top-down polarity is caused by your upright position as a human. This position may extend your visual horizon or, improve your auditive capacity. But, for urban, architectural and technical design, a horizontal front - back polarity is most important. Utensils such as books, computers and furniture have a back and a front (P_{30cm}). They cannot be turned around without losing their function.
A room is polarised into a window, which is open to sensoric impressions (see *Fig. 136*). Habraken[a] has named the resulting open and more closed zones: α- and β-zones. There are, however, also polarisations into a door for motoric possibilities. The gradients of these polarisations diversify your opportunities to arrange your furniture and your activities. The decreasing visual seclusion (darkness) into a window is operational in a nominal radius R = 3m, but the decreasing motoric seclusion extends through the door, opening up the rest of the building in a larger radius R = 10m (see *Fig. 137*). Leaving a building may unveil the next

[a] Habraken(1985) *De dragers en de mensen. Het einde van de massawoningbouw* (Eindhoven) Stichting Architecten Research

polarity of its own front or back (P_{30m}), operational in a radius of R = 30m between 'private' and 'public' (see *Fig. 138*). The operation of any polarity changes by scale.

Orthopolarity

It is remarkable that these successive polarisations are often perpendicular to each other. The R = 30m polarity of *Fig. 138* is perpendicular to R = 10m of *Fig. 137*, and so on ('orthopolarity': $P_{30m} \perp P_{10m} \perp P_{3m} \perp P_{10m}$). The reason may be that orthopolarity offers more possibilities than parallel polarities. The corners of an orthopolar room (see *Fig. 139*) obtain different operational possibilities, and consequently, a different use.

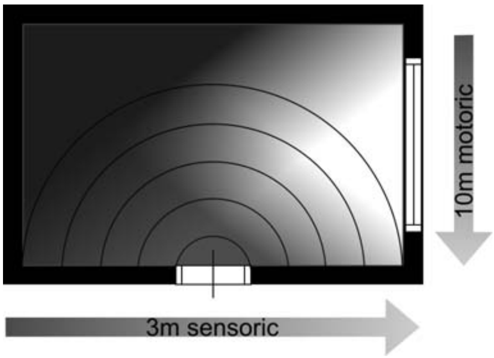


Fig. 139 Orthopolar R = 3m

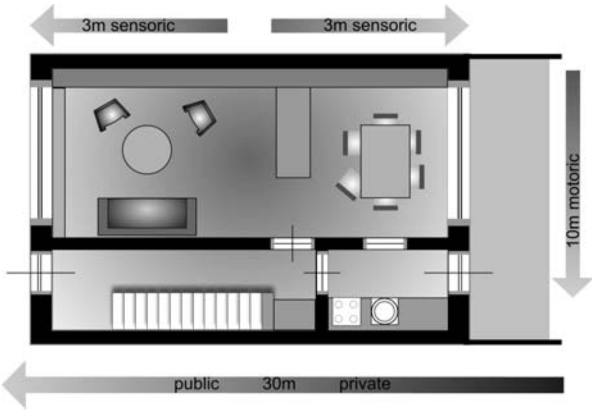


Fig. 140 Orthopolar R = 10m[a]

The room of *Fig. 136* has two different halves: a dark but accessible, and a light but less accessible one. Both polarities are in the same direction (synpolar). *Fig. 139* has four different corners. At this small surface, however, it may not produce more opportunities than the clear dual polarity into opposite directions of *Fig. 136*. The advantages may become even more operational in the radius R = 10m. The dwelling of *Fig. 140* shows 3 orthopolar polarities ($P_{3m} \perp P_{10m} \perp P_{30m}$), which makes different functions possible.
The motoric polarity of *Fig. 140* concentrates connections in a less closed section of the dwelling. The front~ and the back door, the staircase, the cables, pipes and taps for informatics, electricity, gas and water are separated from the less dynamic living and dining room. Architects may testify to their creativity if they propose a staircase or a kitchen in the living room, but it neglects a useful structural diversity.

[a] The '10m motoric' polarity in this figure is obviously shorter than 10m, but similar to the one of *Fig. 137*, and still fitting in the margins of 'nominal' size as explained in *Fig. 17* on page 52.

Synpolar and counterpolar

If you sit along the edge of a forest, (see *Fig. 141*) you will have a view with a backing. Your body, then, has the same polarity as your larger environment (synpolar).
It would feel unnatural to sit the other way around. It would be similar to your position if an old fashioned teacher put you in the corner of a classroom (counterpolar, see *Fig. 142*). Your open side, then, meets closed walls, and you do not know what happens behind your back. If public banks are counterpolar, they offer a view of the road instead of the park.

Fig. 141 Synpolar

Fig. 142 Counterpolar

Fig. 143 Divergent (polarities of the same radius)

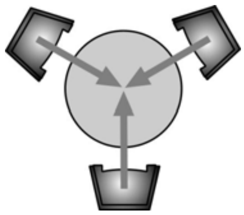


Fig. 144 Convergent

The location of the polarities are the same… …or different

Divergent and convergent polarities

You can recognise divergent structures in different ways: at the top of a hill, in order to obtain different views (see *Fig. 143*), sitting against a wall, standing back to back to protect each others' backs against attacks, or a panopticon, which is a prison that kept the prisoners in view by positioning all of them visually directed into one location of surveillance. A meeting at a table has a completely opposite *convergent* structure, (see *Fig. 144*) with different polarised locations. You may use your polarity to express your dissatisfaction by turning your chair.

Arrangements of polarities

Orthopolar, synpolar and counterpolar polarities combine polarities of a different radius. Divergent and convergent polarities share a similar radius (see *Fig. 145*).

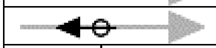
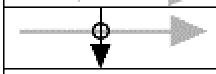
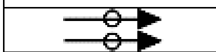
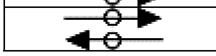
Polarities	Name	#radiuses	#locations	#directions
Combinations of polarities at one location				
	synpolar	≥ 2	≥ 1	≥ 1
	counterpolar	≥ 2	≥ 1	≥ 2
	orthopolar	≥ 2	≥ 1	≥ 2
	divergent	≥ 1	≥ 1	≥ 2
Arrangements of polarities at different locations				
	convergent	≥ 1	≥ 2	≥ 2
	consecutive	≥ 1	≥ 2	≥ 1
	parallel	≥ 1	≥ 2	≥ 1
	counterparallel	≥ 1	≥ 2	≥ 1

Fig. 145 Kinds of polarities

If you look at the minimal number of *locations* (#locations) involved, then a divergent polarisation still can appear at one location (e.g. a hill-top), but convergence cannot. Convergent polarities require at least two polarised locations. *Fig. 137* and *Fig. 138* (opposite buildings directed into a street) already showed a special case of 'opposite' convergence, at a minimum of two different locations. This is no longer a *combination* at one location, but an '*arrangement*' of polarities at different locations. There may be many more arrangements, but it is of little use to give them all a separate name.

Consecutive and parallel polarities, symmetry

In the symmetric arrangements of *Fig. 146*, the open sides of the convergent polarities will meet each other at the street. The closed sides of the divergent polarities will meet each other at the back path. The divergent polarity this time counts more than one location (2). You may, however, raise the back path to obtain 1 'hill top' location.

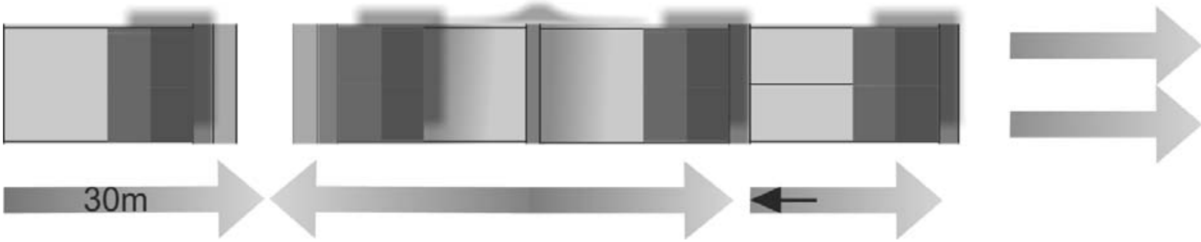


Fig. 146 Opposite convergent, divergent *Fig. 147 Consecutive* *Fig. 148 Parallel*

The open side of the first consecutive polarity in *Fig. 147* meets the closed side of the second, causing a counterpolarity. It decreases the radius of the P_{30m}. Your garden and your sleeping rooms become a public area for your rear neighbour, if you do not close your curtains and build a high fence in your backyard. The fence would, however, destroy the P_{30m} of your rear neighbour. Symmetry may have advantages.

Strengthening weakened polarities

Parallel directions (see *Fig. 148*) do not disturb polarities; counterparallel ones may disturb polarities. Compensations, however, may increase the structural diversity. The counterparallel arrangement of *Fig. 149* has gardens enclosed by side façades, but they are open to the roads. It is compensated by added separations and connections. A sloped garden climbs against a rear wall. The access to the street (used as a back path) is limited to a gate, which is accessible by an excavated path, which is hidden under trees. The lower (more closed) back façades face a visually elongated garden. A separating ditch (catching the water of the sloped gardens and the long roofs) separates the garden even more. It may be extended into a pond. The street fronts show the diversity of high, but open, façades, alternating with closed but lower walls with gates, trees and sunlight on the street. Compensation may diversify.

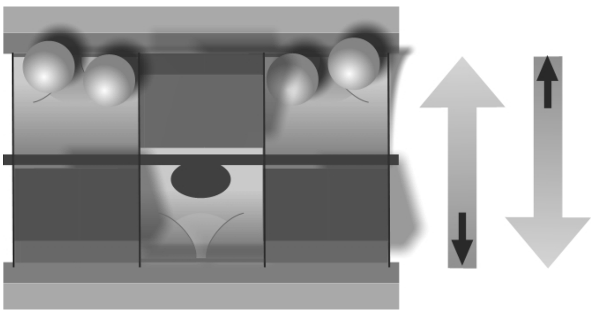


Fig. 149 Compensated counterparallel P_{30m}

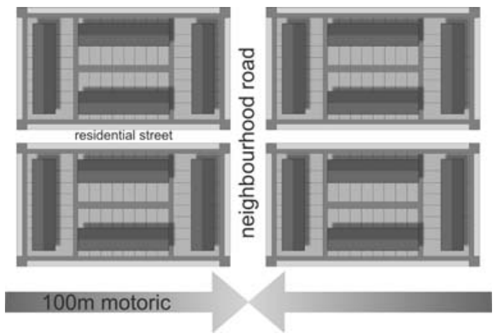


Fig. 150 polarities(P_{100m}(residential street))

Motoric polarities of roads

Residential streets open into crossings with equal or wider roads (see *Fig. 150*), producing a P_{100m};, neighbourhood roads do the same producing a P_{300m} (see *Fig. 151*), and so on. These polarities are stronger crossing a wider road and meeting a larger building height (see *Fig. 152*), but any polarity itself can be strengthened. If a street is 'open' (α) into a crossing, then there is also a 'closed' (β) area inside. You may design a narrow α and a wider β , in order to obtain more 'enclosure' (structure). You, then, can add more difference in parking, plantation, street furniture, lightning and architecture (content and form).

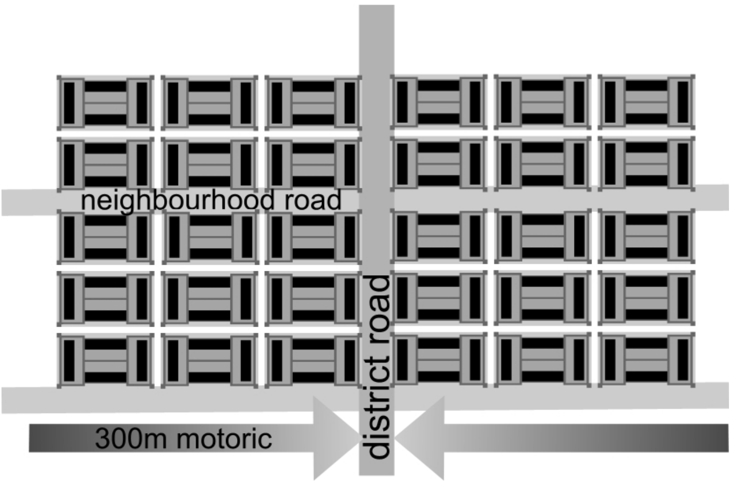


Fig. 151 P_{300m} of a neighbourhood road

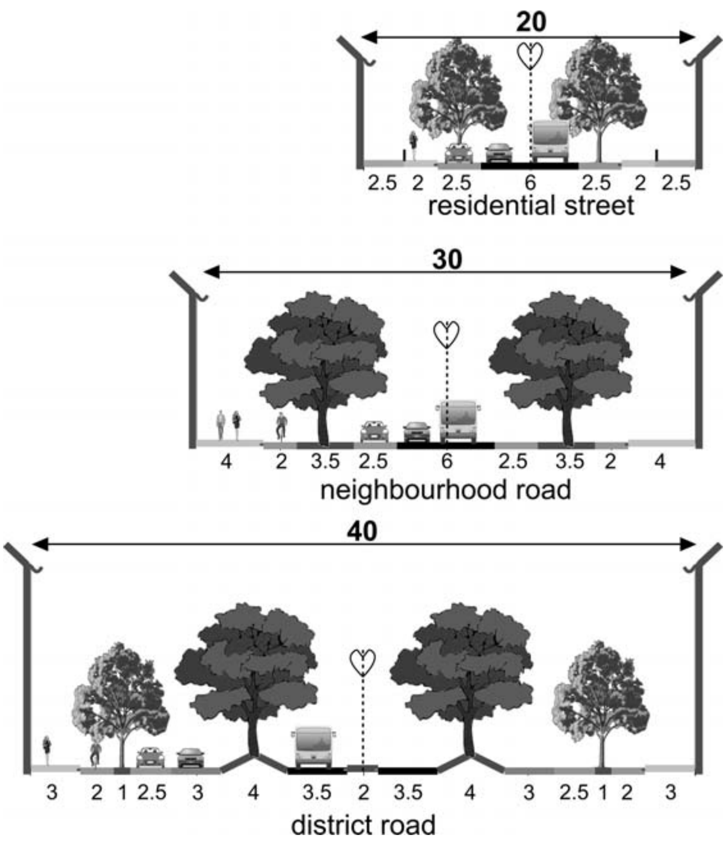


Fig. 152 R=30m Profiles of streets and roads

Sensoric and motoric district polarities
In any urban area filled with buildings and roads appear less closed, less directed and less regulated spaces, such as squares and parks with easy public access. The mere existence of some emptiness may be more important to avoid a kind of urban claustrophobia, than their actual use. They serve your orientation in the urban landscape. Green areas provide an alternative for the usual agenda of urban life through other kinds of life ,without an agenda. If you make green areas accessible at an average walking distance equal to their size expressed in a radius r ('Standard Green Structure', see *Fig. 109* on page 170), then a neighbourhood park r = 100m in every neighbourhood R = 300m (requiring an average walking distance of 100m) will take approximately 10% of the urban surface. A district park r=300m with an average walking distance of 300m will also take approximately 10%, and so on (see *Fig. 153*). *Fig. 153* is a theoretical district R= 1km, approaching the concept of a Standard green structure. It counts 12 residential neighbourhoods at R = 300m, which are arranged around a district centre, which is surrounded by a district road. The standard building groups (see *Fig. 150* on page 191) turn their front into this road. The convergent district roads give access to the centre with a view to the central park.
The 12 neighbourhoods are synpolar to the centre, by parks with a primary school and other local facilities at open squares. The synpolarity, then, contains a motoric district P_{1000m}, a sensoric neighbourhood P_{300m} and a park-square P_{100m}. Some T- crossings offer a focal α point (a building or a park), in order to strengthen a motoric local street P_{100m}.

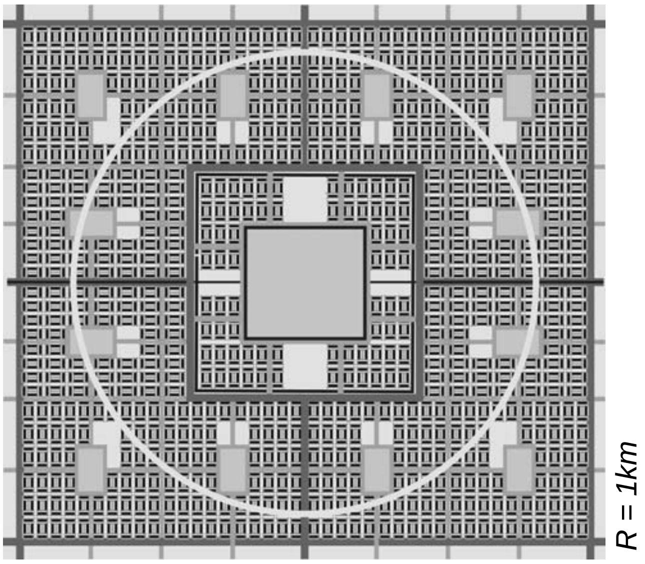


Fig. 153 Dwellings, roads, parks and facilities

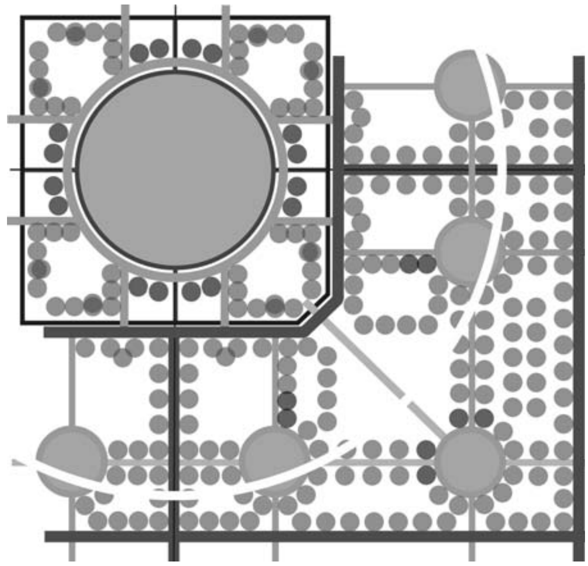


Fig. 154 Redistributing floor space

Strengthening polarities through form
Fig. 154 reduces a quarter of *Fig. 153* into equal floor space by dots r = 30m (representing 3000m^2 floor space or 100 inhabitants). Its redistribution suggests the intended urban concept better by varying densities. This more abstract representation can be discussed and easily changed by replacing dots. It may serve as a 'distributed programme' for architectural detailing. You may allow yourself to interpret a dot within a radius of 100m (dot tolerance). You may assign a designer for detailing a number of coherent dots and adjacent public space, such as two β sides of a street. Any R = 30m dot may be divided into 10 dots (dot division), r = 10m representing 300m^2 floor space; any R = 10m dot into 10 dots r = 3m, and so on, to reach the final stage of detailing.

5.3 Structure without polarities

A third order variable

Values of decreasing seclusion in a spatial sequence ('polarity') are realised by values of primary variables, such as the light in a room, temperature in a house, built-up area in a neighbourhood. You cannot realise any 'openness' or 'seclusion' without these primary variables. Polarity, thus, is a 'second order' variable, or even better (if you accept 'Form' as 'second order' variable): a variable of a 'third order'. It structures primary variables and their form. From many variables, you can classify their extremes as 'open' or 'closed'. Adding more content may strengthen the polarity. For example, differences of temperature, humidity and rules of behaviour usually accompany the polarity$_{10m,}$ between a living room and a hallway (see *Fig. 140*). You may add even more differences to strengthen this polarity (colour, texture or upholstery). In this section, I will study which variables of *Fig. 74* on page 114 are 'polarised' themselves, and which are not (see page 196 and 197). Before doing so, I have to determine if single or combined variables may show a kind of structure themselves, not covered by any polarity.

Ranked values

An environmental variable (see the list of *Fig. 74* on page 114) may develop its own successive values as a gradient in space, without any polarity of seclusion.
For example, the sequence of rock-gravel-sand-silt-clay in the deposits of a former river is a sequence of ranked particle size, without a beginning or an end, to be classified as 'open' or 'closed'. It is *sorted* by some selective polar process in the past, but is it presently *structure*? Does 'structure' (seen its general definition on page 183) also include the set of 'connections' and 'separations' between the values that are ranked in a variable? I would call it 'ranking instead of structure (see *Fig. 155*). These 'connections and separations' do not stabilise a form. The values are not actually separated and connected, but *distinguished* and *ranked* in a variable as a human concept. The natural sequence of rock-gravel-sand-silt-clay in the deposits of a river is stabilised by the surface of the Earth and its gravity, not by human distinction and ordering. What we observe is a gradually changing *texture*, not a stabilising underlying *structure*. If you use the clay to connect separating pieces of rock with some support of gravity into masonry, then you may obtain 'structura' (´brickwork´ in Latin). In that case, it may lose any ranked order (see *Fig. 156*).

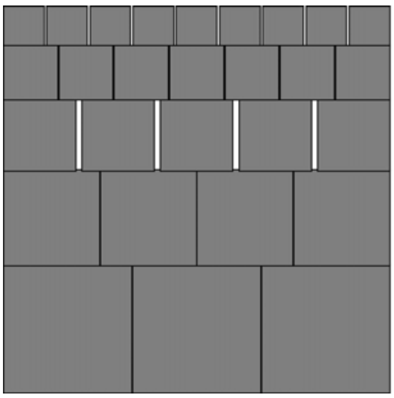


Fig. 155 Ranked order

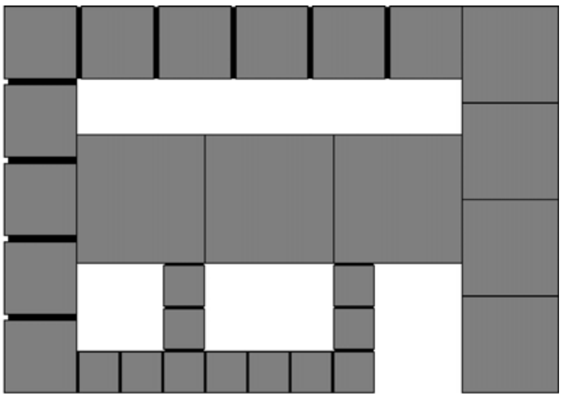


Fig. 156 Structured order

Moreover, Fig. 156 shows that structure supposes form, which is a distribution of values in space. You may recognise regularities (patterns) and a composition, but 'structure' is something else. It is the set of stabilising separations and connections.

Relations between variables

If two variables develop their values parallel in space, then their values become related in a unique combination, at any location in their sequence (see *Fig. 157*).

Fig. 157 Negative and positive ranked spatial relations between two variables.

You may conceptualise the mutual relation of variables in a formula with values connected by mathematical operators (+, −, *, /, and so on). The formula with *separated* values *connected* by operators may have a 'structure', which stabilises its results. Does a reality, however, have the same connections and separations as its simulation, even if the result looks equal? Is its form stabilised by the same (adding, subtracting, multiplying, dividing and so on) operations? A formula or a set of related formulas (a model) is a *procedure*, a sequence in time, an algorithm. It eventually results in a similar pattern if you follow its strict sequence of operations. The same pattern, however, may come into being in many different ways. Moreover, there are many forms and designs that still cannot be simulated or distinguished by mathematical operations, if they do not show sufficient repetition or ordinal sequences to be named as variables (see *Fig. 158*).

Fig. 158 Unranked spatial relations of values in Fig. 157

Mathematical models suppose equality

A mathematical model may be useful for prediction or design, but the results of its equations is still not the diverse reality you may observe, or the possibility you want to design. For example, suppose that you observe a soil somewhere, where the distance (d) from the first stone into the successive gravel, sand, silt and clay appears to be inversely proportional to their particle size (s): d=a/s. Suppose, that you have observed elsewhere, that the size of the deposited particles (s) is proportional to the average velocity (v) of the water transporting them, s=b*v. You, then, may conclude that once there must have been a stream that left the gravel, sand, silt and clay at their successive locations. This model, however, simulates a *process*, that apparently once came to an end by other variables (local geomorphology, geologic movements, climate, human artifacts), stabilising the state of dispersion observed, but not its actual 'structure'.

Stabilising procedures

Stabilising processes can be simulated by optimisation procedures, which are mainly based on matrix calculus.[a] Contemporary geometry has the same basis.[b] A matrix is a table with cells filled with values or formulas for different local states or processes. If the locations in the table refer to the locations of a real surface, then the matrix is a map, simulating different values and processes at every location. If adjacent locations counteract, then the processes may stabilise each other, producing an equilibrium in the direction of their adjacency. For example, *Fig. 159* shows a map with randomly sloped cells. If the rain falls at that surface, then they determine the course of runoff streams, as simulated in *Fig. 160*.

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[a] Lay(2000) *Linear Algebra and its Applications.* (Boston / San Francisco / New York / London) Addison-Wesley
[b] Aarts(2000) Meetkunde. Facetten van de planimetrie en stereometrie (Utrecht) Epsilon Uitgaven

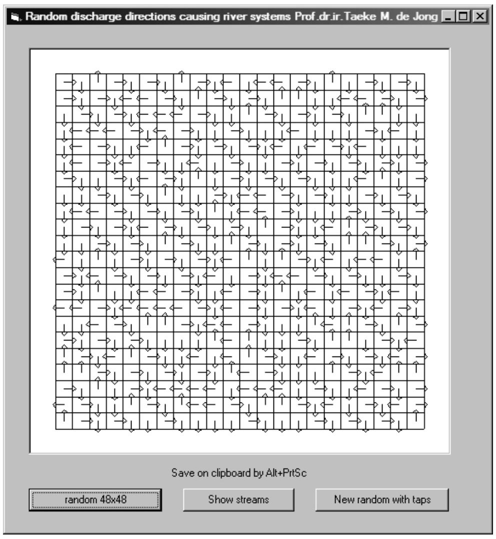

Fig. 159 Directions of slopes

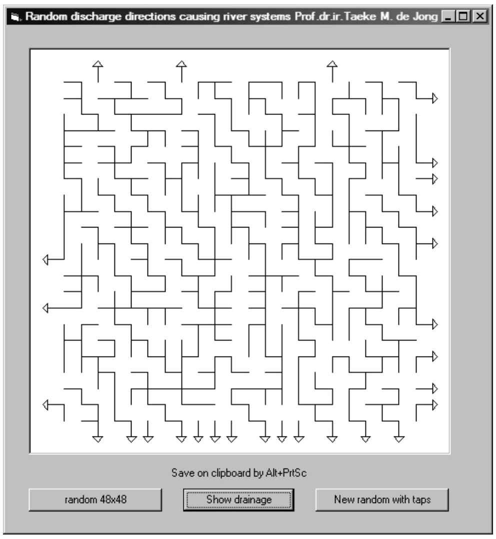

Fig. 160 Resulting course of streams[a]

Fig. 160 shows connections and separations (watersheds) that you know from reality. Optimising models, then, may simulate structures. Moreover, the streams show closed (source) and open (destination) sides: polarities. Is that always the case? Does stabilising symmetric counteractions of values or (potential) processes always produce a polarity in some direction? Let us first investigate whether the variables in *Fig. 74* on page 114 already show a kind of polarity themselves, before they may cooperate with some existent polarity, or neutralise it through counterpolarity. Then, we may answer the question whether there are other variables or structures *without* a relation to successive degrees of seclusion.

Polarised variables

The extreme values of many variables in *Fig. 74* on page 114 immediately remind one of some openness or seclusion. Let me follow the alphabetical sequence of the list. The Access values at different levels of scale are obviously liable to motoric openness and seclusion. Agriculture$_{3km}$, however, ranging between fields and settlements, raises a dilemma. If you speak about 'the open field', then the sensoric connection seems obvious, but in a motoric sense, a settlement may be 'open'. It may serve as a gate to the market, or to a larger society. You may conclude that there is a relation anyhow, but in one or the other way. Allotment$_{100m}$ ranging from detached until attached is no problem, but Altitude$_{30m}$? Is 'high' less closed than 'low'? You may also draw the conclusion that there is a relation, but both ways. Altitude$_{100km}$, however, ranging from lowlands into highlands may be associated with the openness of lowlands and the seclusion of mountainous areas with their valleys. The horizontal or vertical architectural Articulation$_{30m}$ again raises a dilemma. Is 'vertical' more 'closed'? If you remind the many horizontal galleries of flats, then you may indeed associate them with 'openness'. The difference in architecture, as referred to in the paragraph Motoric polarities on page 192, however, may be elaborated as a more vertical articulation at the α corners of the street, and a more horizontal articulation in the inner β zone. If it is related to the higher Altitude$_{30m}$ of buildings at the corners, since higher buildings offer more possibilities for vertical articulation than lower buildings, then it may lead to the conclusion that there is a relation. However that may be, you also may elaborate on it conversely: a vertical articulation in the β zone and a horizontal one in the α zone. Since both are possible, you may conclude that it is the first independent variable of the list. You can relate it to a polarity any way you want. In any case, however, it will strengthen the polarity, simply because it adds a difference between α and β.

[a] http://team.bk.tudelft.nl/Publications/XLS/Rivers(Drainage).exe
http://team.bk.tudelft.nl/Publications/XLS/Rivers(Drainage).zip

Fact, association or possibility

You may argue, that the dependencies concluded above are no more than associations without empirical evidence. That is true, but designers are not assigned to discover truths or probabilities by empirical research. Their task is to invent improbable possibilities. *Possibilities* only may become *true* through realisation. It changes the argument into what is more or less *possible*. In that field of study, you are forced to estimate beforehand instead of measuring afterwards. The estimation that accessible or detached houses should be associated with openness (inaccessible or attached houses with seclusion) is difficult to deny. The question whether there are independent variables in the list, comes down to the question whether a designer could easily deny (and change) a relation of a variable with a sequence of seclusion (including the cases where that relation to the sequence is ambiguous). In other words: are these values useful as legend units in a drawing, without any reference to a sequence of seclusion?

Variables without polarity

A relation of Articulation$_{30m}$, with some degree of seclusion, could easily be denied through design. The next variable is Boundary Richness$_{10m}$, , which ranges between sharp and vague boundaries. It is an ecological term[a] that is mainly associated with transitions in the soil between more homogeneous (e.g. wet and dry) areas. In the gradient of a vague boundary (e.g. with all degrees of humidity), more organisms can find their optimal niche than on the more homogeneous biotopes at both sides. They are separated by a sharp boundary. Biotopes are characterised by many variables. At least one variable substantially changes its values at their mutual boundary. Boundary richness determines the number of intermediate values between its extremes. This is not necessarily related to a sequence of seclusion. Boundary Richness is relevant for design. It can be applied to any variable. It is then at least a second order variable of form, as it distinguishes between vague and sharp forms. If a boundary actually separates both sides, thereby stabilising their difference, then it would be a third order variable of structure. I would, however, call such a boundary a 'border'.
Colour$_{1m}$ seems independent. You can paint colours without any reference to 'open' or 'closed'. But I doubt it. You may associate dark colours with 'closed' and white with 'open'.
Geology$_{10km}$ or History$_{1km}$ are not only independent from a sequence of seclusion, they are even autonomous. They are relevant for design (you can utilise them), but you cannot change them through design, other than to destroy their values.
The other variables that are not necessarily liable to a sequence of seclusion are Ecology$_{3km}$, Life$_{1m}$, Light$_{1m}$, Humidity$_{3m}$, Nature$_{30km}$, Relief$_{100m}$, Size$_{1m}$, Sunlight$_{30m}$, Surface$_{1m}$, Technology$_{3km}$, Technology$_{100km}$, Temperature$_{1m}$, Temperature$_{3m}$.
That limited number of independent variables may vary *in nature* without causing any degree of seclusion, but you cannot vary their values *through design*, without applying some kind of solid material leaving space for their variation. This again implies a polarity at the lowest level of solid matter and adjacent space. But at the larger levels of scale, there still may be structures without polarity.

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[a] Leeuwen(1965) *Over grenzen en grensmilieu's* **IN** *Jaarboek 1964 Koninklijke Nederlandse Botanische Vereniging* p53-54
Leeuwen(1973) *Ekologie* (Delft) TH-Delft, Afd. Bouwkunde 3412b, Vakgroep Landschapskunde en Ekologie Hb 20 A
http://team.bk.tudelft.nl/Publications/2005/Leeuwen/Leeuwen(1973)Ekologie(Delft)THD%203412b.pdf
Leeuwen(1979) *Ekologie I* (Delft) THD 3429
Leeuwen(1980) *Ekologie II*. (Delft) THD 3416
Westhoff;Bakker;Leeuwen;Voo(1970) *Wilde Planten - Deel 1. Algemene inleiding, duinen en zilte gronden.* ('s-Gravenland) Vereniging tot behoud van natuurmonumenten in Nederland p164-169

Structures without polarity

The question in the beginning of this section was, whether there is a kind of 'structure' independent from any sequence of seclusion. The independent variables summarised above may be related through design into a structure without such a polarity. A straight wall in the open field does not have to enclose anything to be a structure stabilising different values of any independent variable at both sides of the wall. It may be used to grow grapes at the sunny side, generating shadows on the other side, even without enclosing a garden. Access of sunlight is related with temperature, humidity or conditions of life. In that case, however, the locations at both sides are still more and less 'closed' to sunlight. A screen may protect you against the wind without enclosing anything, but it still has sides more and less 'closed' from the wind. Both polarities may be counterpolar. Because the sunlight and the wind are vector fields with changing and even different directions, separations and connections will not make them as stable as an enclosure in any direction would. You may conclude that non-enclosing structures offer less 'structure' than enclosed ones. It is even more the case with non-vector variables, such as humidity, temperature or other conditions for life. They are dispersed in any direction if they are not regulated by vector fields of sun, wind, rain or runoff. In nature, you may find many 'weak' (non-enclosing) structures, which stabilise differences in one direction. In the other directions, distance may play a role as an enclosing separation. Design, however, mainly reduces these distances through separations, and bridges them through connections. Distance may be used as a separating factor in environmental zoning around industries and installations, in order to reduce nuisances. But, even then, design may look for material source-directed separations, in order to save space. In mechanical engineering, non-enclosing structures may play a role (jet-propulsion, military devices such as defence walls or guns), but in spatial design and biology, degrees of seclusion play a prominent role. In the next section, I will neglect these 'weak' polarities, and limit myself to structures that are dependent from some sequence of seclusion.

5.4 Polarities larger than 1km

Lessons from the smaller polarities

Section 5.2 described different polarities operational until 1km :

P_{1m}: front and back of people, furniture and utensils;
P_{3m}: window-side and inner part of a room;
P_{10m}: direct accessible and less accessible parts in a building;
P_{30m}: public areas in front of buildings and private backyards;
P_{100m}: crossings, access parts and inner parts of streets, courts, cul-de-sacs;
P_{300m}: green, paved, built-up, nature and culture in neighbourhoods;
P_{1km}: residential and central parts of a district.

The difference between visual and actual access resulted in a distinction between sensoric and motoric polarities. At some levels of scale (R = 3, 30, 300m), the sensoric polarities seemed to be dominant; the motoric polarities dominated at the other levels (R = 10, 100, 100m). Different cooperating or counteracting polarities appeared to be possible at the same location. Polarities at different locations showed arrangements of cooperating or counteracting polarities that are so commonly known, that they could get their own name. Compensations of counteracting polarities appeared to be interesting from a viewpoint of environmental diversification. They diversified form and content at lower levels of scale. Polarities could be strengthened or weakened by adding variables. Many of these variables contain values that can be associated with openness or seclusion themselves (see page 196).

Grain and directions

Referring to the theoretical district of *Fig. 153* on page 193, *Fig. 161* shows the R = 1km part of this model more precise at the same scale as *Fig. 162*. Compared to the closed building blocks of the city of Amsterdam (see *Fig. 162*), the minimal grain r of the model is smaller than it is often found in reality. To visualise P_{1km} better and to make it manageable for design, *Fig. 154* on page 193 reduced it by dots r = 30m representing 3000m^2 floor space or 100 inhabitants. A lower resolution R/r makes a P_R more recognisable.

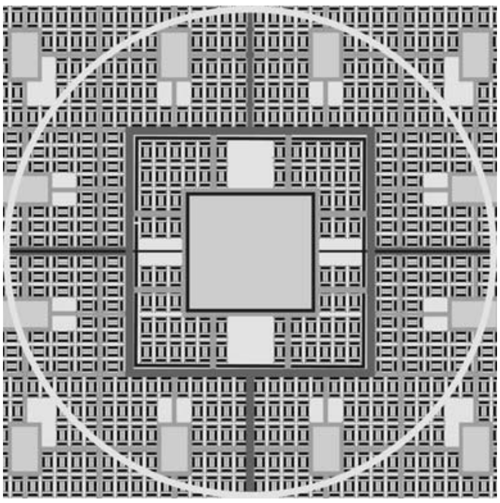

Fig. 161 R = 1km frame, r = 10m grain

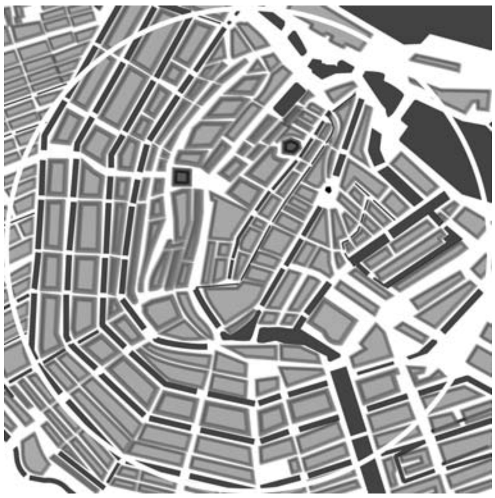

Fig. 162 Amsterdam city R = 1km, r = 30m

The diversity of sizes and directions of *Fig. 162* diversifies the polarities mutually through their form. The copy-paste regularity of *Fig. 161* can be diversified only by content and function. Counting the number of street corners and angles passed from a location to reach any other location is an indication of its ‘connectivity’ or centrality, known as Space Syntax developed by Hillier[a]. Calculated from the most connected location, you then have to pass a minimum of turns into any other location. Minimising them reduces the resistance of customers to go shopping.

Fig. 163 R=3km detail of Fig. 98 and Space Syntax analyses[b] at 2 levels of the same area

The minimal diversity of sizes and directions of *Fig. 161* however, minimises the number of street corners for any location. Space Syntax, then, only diversifies in ‘deformed grids’. Compared to connectivity values of a totally regular grid, it may offer a degree of morphological diversity, or ‘structural complexity’, which determines its motoric resistance .The motoric P_{3km} that is described below is similar to the previous motoric P_{1km} described on page 193, but P_{10km} again may appear to be sensoric.

Polarities of towns and conurbations

The motoric polarities P_{3km} from the periphery of a town into its centre produce a very common convergent arrangement (see *Fig. 164*). It is experienced along the main roads into the central city inwards and outwards, accompanied by increasing or decreasing density and dynamics. You could, however, add more content.

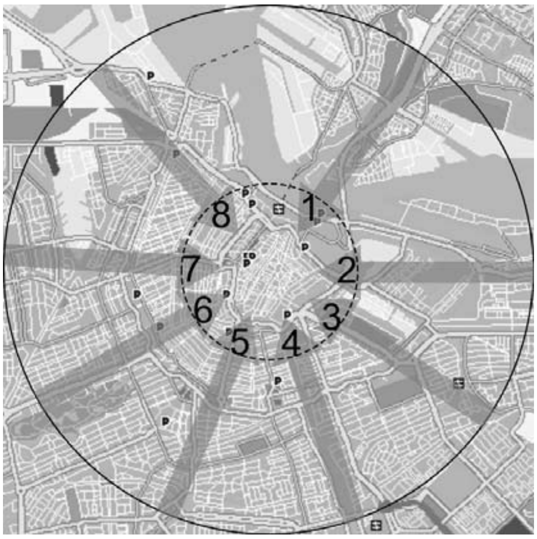

Fig. 164 Amsterdam motoric P_{3km} [c]

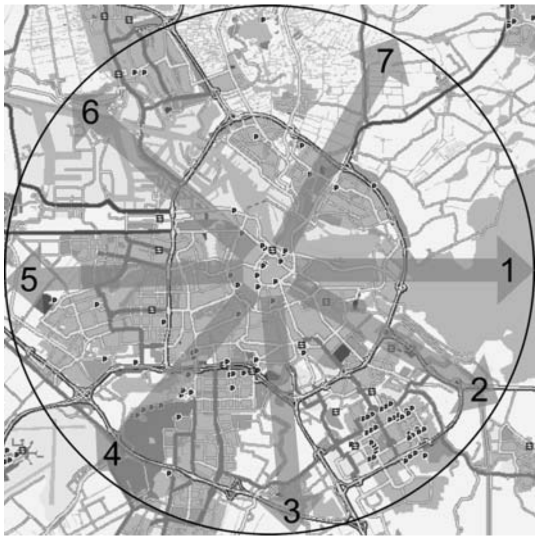

Fig. 165 Amsterdam sensoric P_{10km} [a]

[a] Hillier(1999) Centrality as a process: accounting for attraction inequalities in deformed grids (Urban Design International,)4 3&4 p 107-127
[b] Map elaborated and Space Syntax analyses by Akkelies van Nes(2012)
[c] CityDisc(2000) Den Haag

You may add different variables for different polarities (1-8 in *Fig. 164*). Particularly the α and $\alpha\beta$ locations, where arterial roads connect to the central city or to an intermediate ring road, could be elaborated as urban squares that subsequently synpolarised themselves through parking, public transport stops, and gates into the city named as Northgate, Eastgate and so on. Railway stations, such as the Gare du Nord in Paris, are synpolarised at an even smaller scale, offering a strong urban orientation.
The sensoric polarities P_{10km} into the landscapes surrounding a conurbation produce a divergent arrangement (see *Fig. 165*). Their diversity is dominated by the landscapes and the large parks, which eventually serve as their forerunners. Many ecological variables, such as tree species characterising roads, parks and districts, are available to strengthen them. Amsterdam has a rich R = 10km structural diversification, e.g. compared to Rotterdam. The 7 polarities of *Fig. 165* refer to a great diversity of surrounding landscapes:

1 The great lake IJsselmeer, the former access to the sea and its colonies
2 The sandy Gooi landscape with expensive residential villages
3 The river Amstel and the peat lake area surrounding its course
4 The open polder area of the Haarlemmermeer with its airport Schiphol
5 The area behind the coast until its sandy dunes
6 The harbour area
7 A peculiar polder landscape appropriately named 'Waterland'

Outside the urban area, 10km polarities (e.g. between forests and open areas) produce a structural diversity that is important for birds (and human recreation).

Regional polarities

Present conurbations mainly have been developed at the most accessible locations (rivers, roads and their crossings). The less accessible parts (mountains, moors) have been left for nature, agriculture, smaller towns and villages with smaller territories, in a landscape of convergent polarities around them (a Christaller hierarchy of central places[a]).

Fig. 166 Randstad motoric P_{30km} [b]

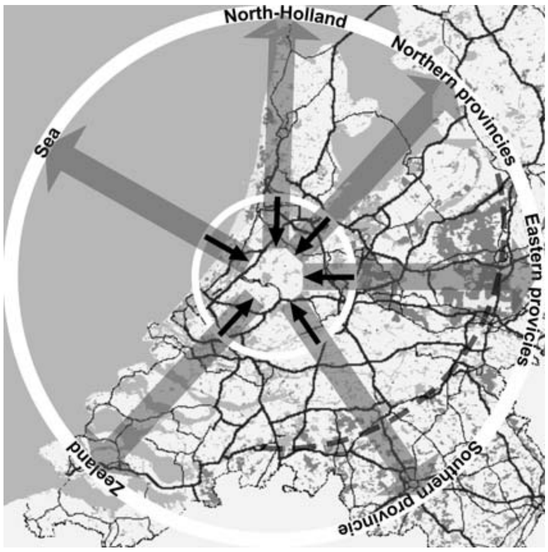

Fig. 167 Holland sensoric $P_{30, 100km}$ [c]

[a] Christaller(1933) Die zentralen Orte in Süddeutschland: eine ökonomisch-geografische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen (Jena) G. Fischer
[b] CityDisc(2000) Den Haag

A regional symmetry

In the Netherlands, the old river Rhine flowed from Utrecht in the East into Leiden in the West through the extended moors of Holland drained into the North by the river Amstel and into the South by de river Rotte. The moors were probably used as hayland (in Dutch 'hooiland', probably a better origin for the name 'Holland' than the official one[a]).
At their East and West boundaries, the North-South traffic may have offered Utrecht and Leiden crucial intersections with the still existing Old Rhine (Oude Rijn).
The Old Rhine, however, was cut off in 1122 AD due to frequent flood events in Utrecht and Holland. The main course of the river Rhine was replaced Southwards. The dam on the river Rotte prevented floods from the Rhine in the Southern parts of Holland and the Rotte-dam (Rotterdam) became the final central place in the South, just as the Amstel-dam did in the North against the floods from the IJssel-lake.
This structure clarifies the remarkable symmetry of the Rotte and the Amstel draining Holland in opposite directions with large cities at their ends, perpendicular to the axis of the still existing river Old Rhine between Utrecht and Leiden. The central moors (Holland) became increaslingly occupied in diked polders, drained by wind mills, exploited for cattle, and its peat being excavated for fuel. By doing so, the water level in Holland subsided below the levels of the IJsselmeer and the Rhine, forcing to build more dikes and outlet canals. The Old Rhine became one of these canals, now flowing between dikes. The present 'open' Green Heart of the Randstad now shows a reverse convergent sensoric polarity, which is protected by law, and represented as counterpolar in *Fig. 167*.
The R = 30km Randstad enclosing its Green Heart is surrounded by less dense provinces, in a radius of R = 100km. Each direction shows a different kind of 'openness', resulting in a divergent sensoric polarity (see *Fig. 167*). The Eastern and Southern polarities, however, are crossed by a remarkable second ring of towns and conurbations, at 80km around Amsterdam. It may suggest emerging other polarisations that are weakening the Eastern and Southern polarities.

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[a] Veen(1990) Etymologisch woordenboek (Utrecht) Van Dale lexicografie

Continental and fluvial polarities

A continent is opened up into the sea by rivers. Highways and railways follow their course. You may call the polarities P_{1000km} , which are produced by such rivers, 'fluvial' polarities (see *Fig. 169*).

Fig. 168 $P_{continental,\ fluvial}$ and Rivers P_{300km}

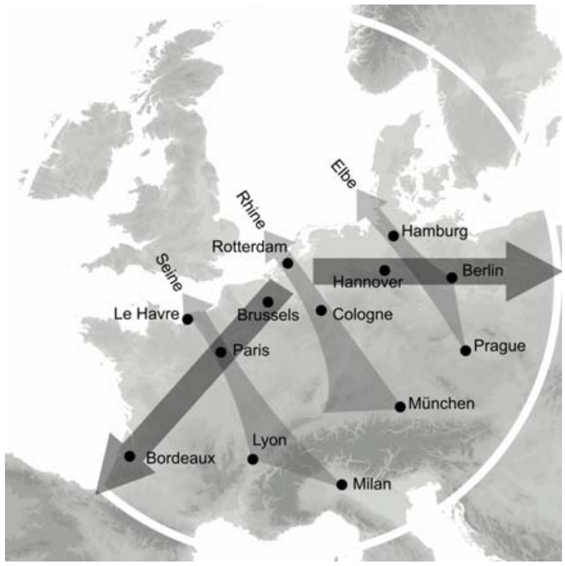

Fig. 169 Rivers P_{300km} crossed by P_{3000km}

Ways with a 'continental' (R = 3000km) reach cross them at some distance from the coast. The coastal routes from the Randstad into Eastern and Southern Europe, then, may be concerned to be part of a bipolar 'continental' P_{3000km}. In its North-West corner, the Amsterdam airport offers access from the sky, and Rotterdam harbour from the sea into this polarity.

The rivers Elbe, Rhine and Seine offer Berlin, Randstad and Paris a 'crucial' position, where they cross the main coastal routes. The other way around, the inland position of Paris and Berlin, determined the distance of the main roads to the coast. These conurbations require a region of R = >100km to surround them, in order to obtain a sufficient centrality for a capital status. This radius, then, requires a separate coastal harbour in their territory (Le Havre and Hamburg) to obtain an international status. At a similar distance, Rotterdam serves as the harbour of the 'Metropolregion Rhein-Ruhr' (Köln, Dortmund, Düsseldorf, Essen)) and the former German capital Bonn. Paris, Berlin and the Metropolregion Rhein-Ruhr (passing Cologne as its harbour). They show a straight line with a similar distance to the coast. This structure allows a slightly different interpretation of P_{3000km}.

Polarities in a radius of 300km

In a radius of R = 300km, smaller rivers polarise their harbours along the coast. At this level of scale, the continental and fluvial polarities appear as highways. Traffic networks follow their own laws of hierarchy (see *Fig. 101* on page 165). The suggested hierarchy in *Fig. 168* may gradually change in a more direct connection between Paris and Berlin. The Randstad may become the harbour of the 'Metropolregion Rhein-Ruhr' at the Rhine-axis. It came into being through the Industrial Revolution, based on coal. Coal mining was concentrated along a line from the Belgian Borinage to the German Ruhrgebiet. Its historical infrastructure crosses the river Rhine near Köln (Cologne), as a historical 'Coal-axis'. It is a potential short-cut in the P_{3000km}. The next section proceeds in a more structural way, where the morphological study concerning the distribution of lines stopped (see section 0 on page 164).

5.5 Networks

Artificial networks

The hierarchy of polarities may be clarified by studying the accompanying artificial networks, as a special kind of structural diversification. Rivers flow one way, from high to low, into the open sea. Their one-sided feeding branches get the form of a tree (see *Fig. 160*). A network of roads, however, is not necessarily 'open' at one side and 'closed' at the other side. Its meshes are at least two-sided, 'bipolar', and connected. The individual user may experience one polarity in the direction of her or his destination, but the arrangement of roads, used by many users both ways, requires a lattice instead of a tree[a] (see *Fig. 170*).

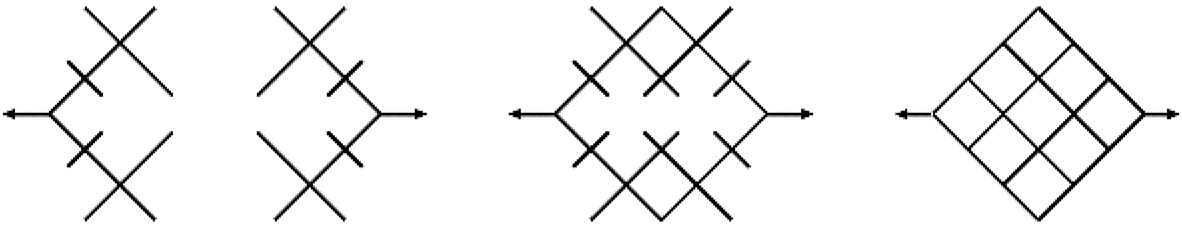

Fig. 170 A polar tree becomes a bipolar lattice

The form of the grid is not necessarily orthogonal, or even made up of square meshes, as it will be represented below for reasons of clarity. The grid may be irregular, but as soon as it contains a hierarchy with longer stretched lines of higher order, there is a tendency towards orthogonal arrangement (see *Fig. 99* on page 164). Irregular meshes, however, do have a perimeter/surface proportion. It makes them comparable with those of the squares. This proportion is 4 km/km^2 for a 1km x 1km square, but because the boundary is shared with adjacent squares, the 'network density' d equals 2 km/km^2. A 2 km x 0,66 km rectangle has the same network density. You cannot keep the same network density by narrowing a mesh that is proportional to its elongation (see *Fig. 102* on page 166). Elongation reduces the number of crossings until there are only parallel roads at a distance 1/d without side roads connecting them. Such a pattern of unconnected parallel lines is no longer called a network.

A road hierarchy

Connecting locations at larger distances requires larger roads where you can drive faster, and be undisturbed by crossings. The optimal reduction of investments, detours and loss of time may be reached if every third residential street is a wider neighbourhood road, if every third neighbourhood road is a wider district road and so on ('factor 3'[b]).
It may produce a hierarchy of roads, as summarised in *Fig. 171* , and drawn in *Fig. 172*.[c]
Fig. 171 refers to the radius of the served estates (10 inhabitants), ensembles (100 inhabitants), neighbourhoods (1000 inhabitants) and so on, as they are conceived of in the previous section. The length of the radius also serves as the length and width of (square) meshes (the distance between exits), which results in the typical network density of each road category (basis of comparison with irregular grids). The increasing design velocity requires wider lanes. A larger road requires more lanes, parallel roads, cycle paths and noise barriers, resulting in a larger width between the façades. Until the metropolitan highway, the slowly increasing capacity is not proportional to the increasing intensity that you may expect from an exponentially increasing served population, even if they use every larger road less per day, or per hour. If you leave a road category out, then the next will take over, increasing its exits, and probably causing traffic jams.

[a] Alexander(1977) *A pattern language* (New York) Oxford University Press
[b] Nes;Zijpp(2000) Scale-factor 3 for hierarchical road networks a natural phenomenon? (Delft) Trail Research school
[c] See http://team.bk.tudelft.nl/Publications/XLS/03bTrafficnetworks.xls to simulate alternatives and to draw profiles.

	m width between façades	m mesh size	km/km2 network density	Served inhabitants	km/hr design velocity	m lane width	# vehicles/hour capacity	# vehicles/hour intensity	# lanes
residential path	10	0,03	70	10	10	1,75	500	2	1
residential street	20	0,1	20	100	30	2,25	2 000	20	2
neighbourhood road	30	0,3	7	1 000	50	2,75	3 000	202	2
district road	40	1	2	10 000	70	3,25	4 000	1 042	2
urban highway	60	3	1	100 000	90	3,25	8 000	2 220	4
conurbation highway	70	10	0,2	1 000 000	110	3,25	16 000	10 400	8
regional highway	80	30	0,07		130	3,25	20 000	16 200	10
metropolitan highway	100	30	0,07	10 000 000	150	3,25	32 000	24 000	16
national highway		100	0,02		150	3,25			8
fluvial highway		300	0,007		150	3,25			4
continental highway		1000	0,002		150	3,25			4

Fig. 171 A hierarchy of roads

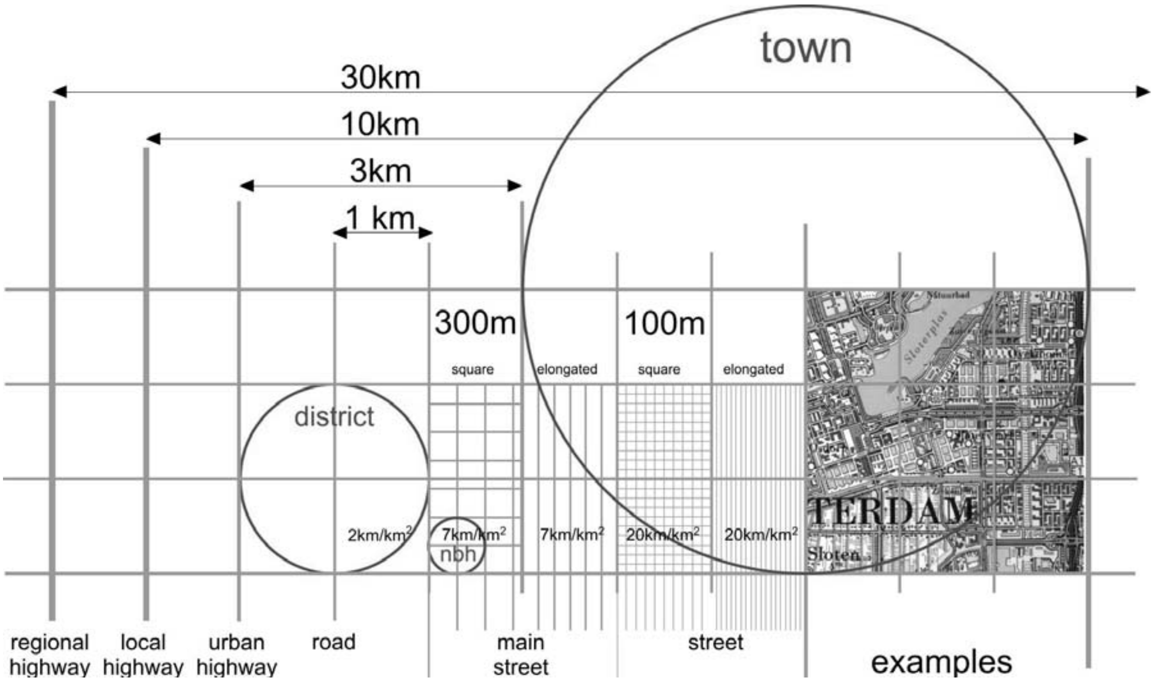

Fig. 172 Dry networks

The theoretical 'factor 3' results in 11 road categories. You may recognise the first 7 categories on a city map (see *Fig. 173*).

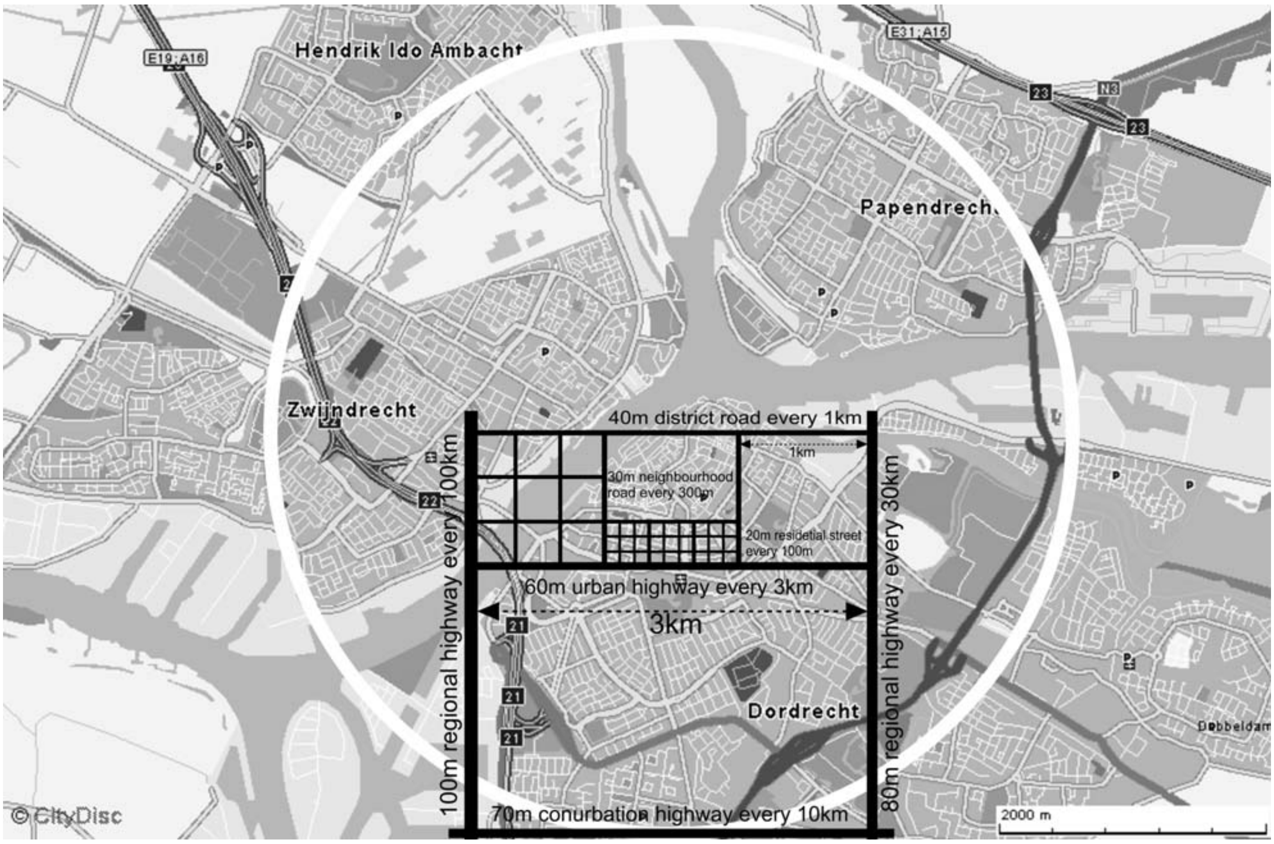

Fig. 173 R = 3km Dordrecht Seven road categories in a city map[a]

National and regional highways

According to *Fig. 171*, the theoretical mesh widths of continental, fluvial, national, regional and conurbation highways are 1000, 300, 100, 30 and 10km respectively. If the continental connection of *Fig. 168* operates as a primary national highway by superposition, then you should expect the next national highways at an approximately 100km distance of the first. In the highways of the Netherlands, you indeed may indicate two 100 x 100km slightly deformed meshes, which are linked up with the Eastward and Southward continental connections (see *Fig. 174*). It would result in two North-South and three West-East national highways. The fluvial South-Eastern connection distributes its traffic flow in Utrecht over the continental connection into Rotterdam, The Hague, Leiden, Amsterdam and the regional highways. In *Fig. 174*, the regional highways are simulated in elongated meshes, with approximately the same network density as a 30 x 30km mesh.

Settlements or connections as driving force

Fig. 175 shows the real distribution of highways, the urban population and the remaining relatively open spaces of the Netherlands as its counter-form. The location of settlements and open spaces may have determined or deformed the theoretical network, but connections and crossings also determined their location. The driving force may be different at different levels of scale.[b] *National* infrastructure works did not improve the economy of peripheral regions (Delfzijl), but *international* connections may improve the economy of cities (Lille by the Channel tunnel). If the classifications of 3m, 30m, 300, polarities as ‘sensoric’,

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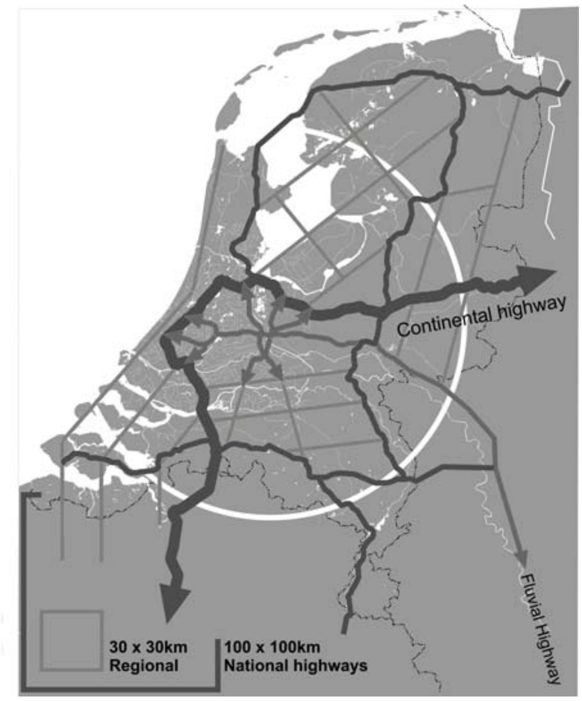
[a] CityDisc(2000) Den Haag

[b] Jong(1998) Wat eerst: wonen, water, wegen of welvaart? Wat aanvankelijk een verband lijkt, blijkt soms toeval. **IN** Angremond;Huisman;Jong;Schiereck;Thissen;Broos;Herbergs**,** Watertovenaars. Delftse ideeen voor nog 200 jaar Rijkswaterstaat (Rotterdam) bèta Imagination Publishers p42-52 http://team.bk.tudelft.nl/Publications/1998/Wat eerst.htm

and those of 10m, 100m and 1000m as 'motoric' are right, then a 1000km connection may be a driving force, but a 300km connection might not. Urban design may start through the connections, or by the built environment, but the best way may be scale dependent.



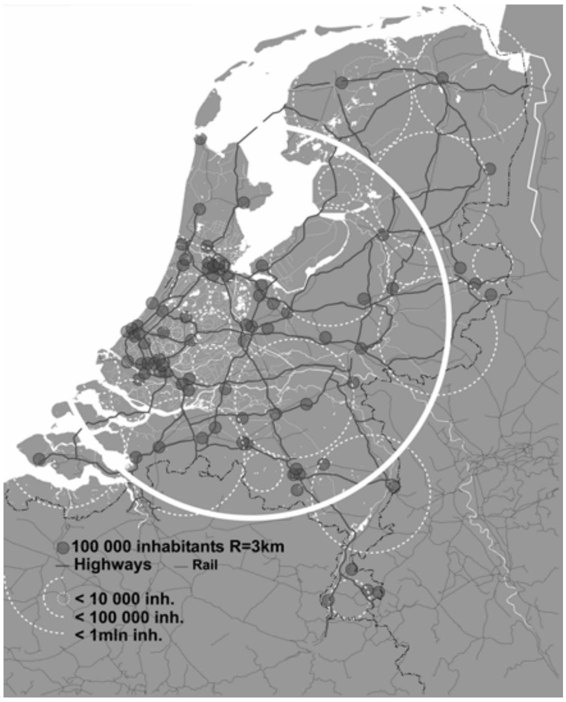


Fig. 174 National and regional highways *Fig. 175 Distribution of urban population R=100km*

Artificial wet networks

Artificial wet networks in lowlands have several functions, including drainage, and serving as a water supply in the summer. The water may flow both ways, making them bipolar. Their hierarchy is surprisingly similar to the hierarchy of the road network above (see *Fig. 176*).

NETWORK		WET		DRY	
km/km^2 density	km mesh size	m width 1%	NAME	m width	NAME
70	0,03	0.3	**trench**	10	**residential path**
20	0,1	1	**small ditch**	20	**residential street**
7	0,3	3	**ditch**	30	**neighbourhood road**
2	1	10	**watercourse**	40	**district road**
0,7	3	30	**race**	60	**urban highway**
0,2	10	100	**brook/canal**	70	**conurbation highway**
0,07	30	300	**river/waterway**	80	**regional highway**
0,02	100	1000	**stream/pond**		**national highway**
	300	3000	**lake**		**fluvial highway**
	1000	$\geq$10000	**sea**		**continental highway**

Fig. 176 Similarities between wet and dry networks

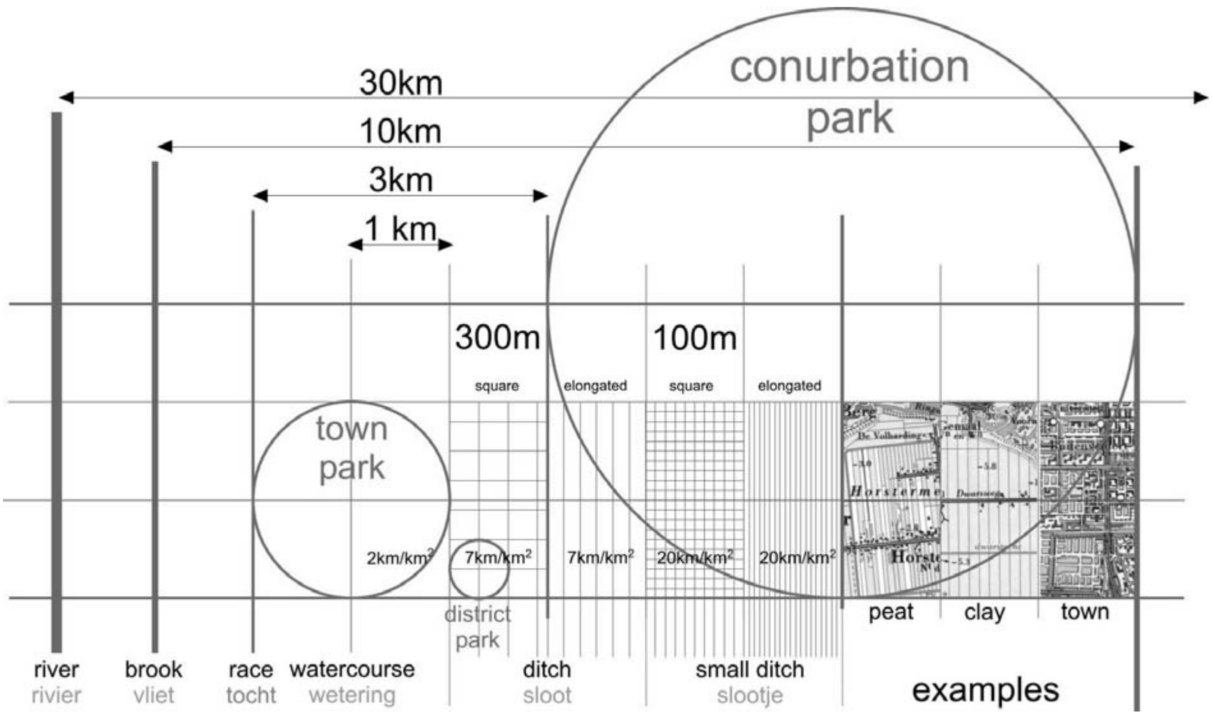


Fig. 177 Wet networks

Fig. 177 shows the wet equivalents of *Fig. 172* , with examples of small, elongated ditches on peat soils, larger elongated ditches on clay grounds, and small square watercourses on sandy urban soils. The drainage distance of small ditches, however, is dependent on factors other than the permeability of soil (peat, clay, sand), such as the precipitation, the desired groundwater level and the desired difference of water level in between the drains.[a]

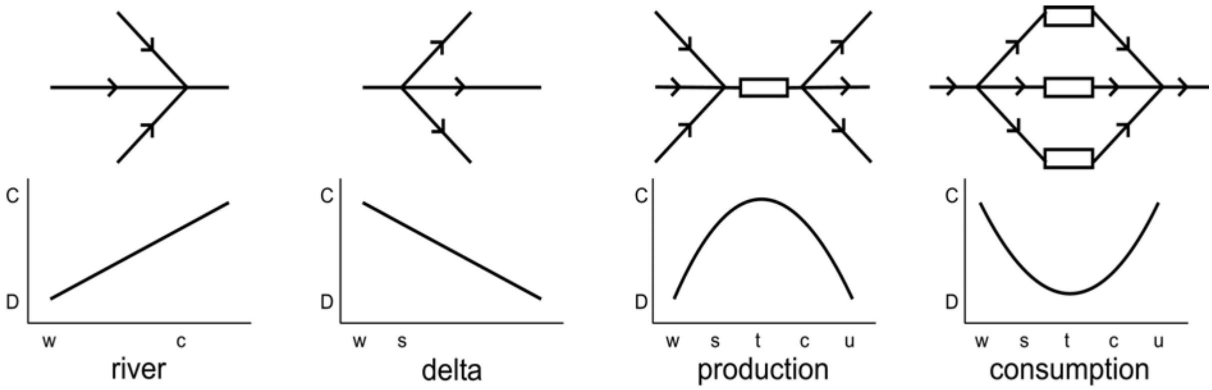


Fig. 178 Collecting, distributing, processing logistics

[a] See http://team.bk.tudelft.nl/Publications/XLS/03aWater.xls

One-way artificial networks

Many other artificial networks, however, are polarised. Cables, pipes, and the logistics of production and consumption in general, are one-way systems, with an input and an output. Their structure contains collecting and distributing phases, with processing operations in between (see *Fig. 178*).Collecting and distributing phases are well-known from rivers and deltas. Collecting phases concentrate (C), while distributing phases de-concentrate (D). Production is a process between winning (w) and use (u). The process contains phases of selection s (e.g. a blast furnace selecting iron from ore), transformation t (making components) and combination c (assembly). These phases determine the content, form and structure of products, which may be a sequence of decreasing energy and nuisance at different locations, with different kinds of transport in between. Consumption, mainly dispersed in households, is a set of similar processes between distribution (goods and services) and collection (labour, leisure and waste).

Urban flows

These flows of materials, energy or information, are mainly neglected in macro- and micro-economics, and in urban design. Intermediate deliveries do not play a role in the calculation of a gross national or regional product. They are difficult to register, and they change through every transaction. A meso-economic method to understand these flows is input-output analysis, a matrix of (mainly industrial) branches at both axes and their mutual deliveries in every cell. From a viewpoint of urban design, however, it may be useful to determine at which level of scale the processing and transport operations can be centralised or decentralised, and which infrastructure can be built to combine them (see *Fig. 179*). Centralisation starts at the baseline of individual survival with collection (raising lines in *Fig. 179*). Selection, transformation and combination have been centralised through the evolution of technology (specialised processing and transport). This requires a distributive system (descending lines) into the end users. Many more dots and lines can be drawn to follow and estimate the centralisation or decentralisation of economic branches, and their mutual deliveries and dependencies.

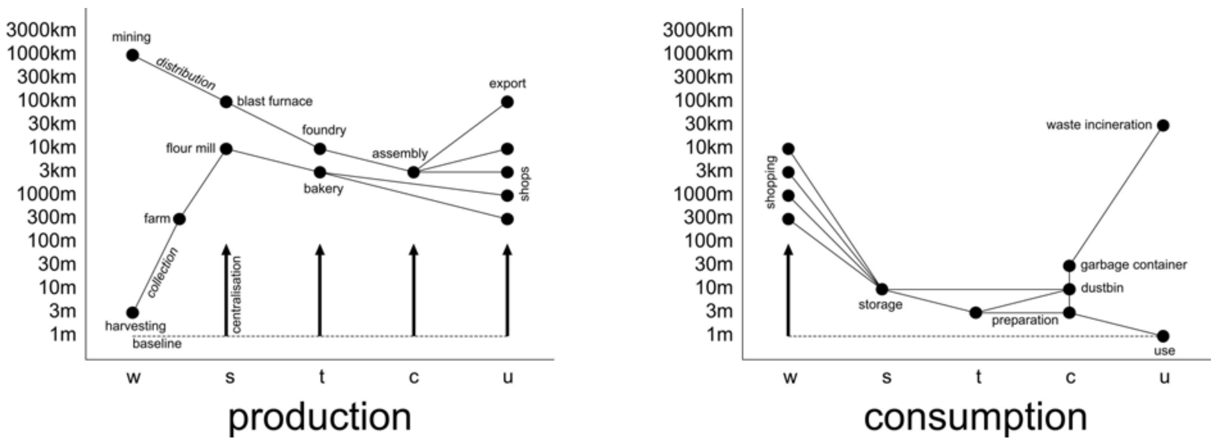


Fig. 179 Spatial logistics

5.6 Structural diversification

Existing structural diversity R=1km

Fig. 180 shows a R=1km area at the boundary of an urban area between a waterway and a highway. This already offers a P_{3km} and a P_{1km} for diversification. An orthopolar arrangement of P_{300m}. around the P_{1km} ,then, seems obvious.
This analysis into rigid arrows may unveil an existing diversity, but to use and develop that diversity through design, you should make the instrument of polarity more flexible. Forget the rigidity of the arrows, remember that its scale is *nominal*, covering a range of scales, even overlapping its neighbours (see *Fig. 17 Defining Nominal* on page 52).
Draw polarities by hand. Mistakes are a source of new ideas. The computer is filled with probabilities. Take a step outside this area of probability into the realm of less probable possibilities (see *Fig. 2 Possible, probable, and desirable futures* on page 17).

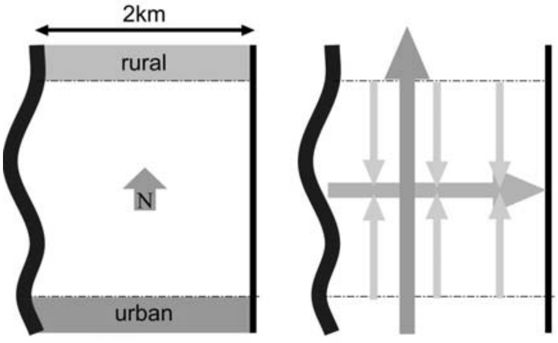


Fig. 180 R=1km Existing polarisations

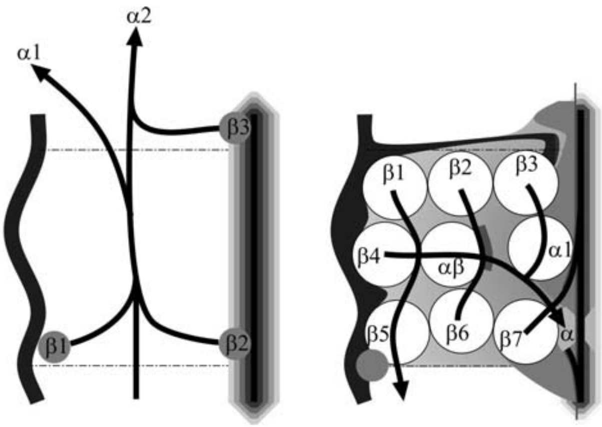


Fig. 181 Splitting, curving, combining

Diversifying a 3km polarity

Splitting and curving the P_{3km} , produces a sketch for primary appointments (see *Fig. 181*). Open views α1 (water) and α2 (rural) should be protected and gradually prepared within the urban area, according to the direction of P_{3km}, starting in $\beta 1_{3km}$, $\beta 2_{3km}$ and $\beta 3_{3km}$.
The Southern part should be different from the Northern part. This includes an intended difference between the Northern $\beta 3_{3km}$ and the Southern $\beta 1_{3km}$ or $\beta 2_{3km}$. The difference between the obviously quiet Western $\beta 1_{3km}$ and the dynamic Eastern $\beta 2_{3km}$ or $\beta 3_{3km}$ (e.g. a noisy swimming pool) is determined by P_{1km}.

Diversifying a 1km polarity

Splitting, curving and combining P_{1km} with the P_{300m} arragement, enables a second sketch by hand. This suggests a branched main road connecting the neighbourhoods to a given highway exit for further discussion. The 9 circles at R=300m provide ample space for 10 000 inhabitants and jobs. This low gross density is chosen for reasons of clarity. Drawing these circles carefully determines a proper dispersion of P_{1km} branches. It provisionally suggests possible extensions of the waterway, a park system, and the location for a district centre. It also develops the previous β_{3km} ideas further. The P_{1km} is not only motoric. Its sensoric character may suggest an increasing green density of plantation in the East. The Eastern neighbourhoods at the highway $\beta 3_{1km}$, $\beta 7_{1km}$ and $\alpha 1_{1km}$ (locating the jobs) may contain the most dynamic functions; the Western neighbourhoods on the waterfront $\beta 1_{1km}$, $\beta 4_{1km}$ and $\beta 5_{1km}$ provide quiet locations. The central $\alpha\beta$ neighbourhood with its adjacent district park provides space for district facilities. It produces a second P_{1km} arrangement, which is not to be discussed here.

Different residential identities in R=3km

The open α_{3km} (views at the still open land) and the closed β_{3km} (specific potentials at the corners of the area) have got a strong locational identity, but how to realise the values in between α and β of P_{3km} as a gradient? What is a useful content or form to diversify that part of the structure, and to make your orientation between South and North in the district self-evident? The variables of *Fig. 74* on page 114 provide many possibilities, but suppose you choose to vary the degree of seclusion of dwelling types (see *Fig. 182*). Detached houses are most open to the environment, and split-level drive-in dwellings in rows are more closed. Many more values may be defined legally, in order to diversify this variable in the regulations of the plan. But this form variable is related to density, economic value, status, age and lifestyle. Do you want to add these inherently related values? Do they fit in the area? You cannot avoid functional considerations here, but they fit in a coherent view on content, form and structure. A higher density in the Southern part than in the Northern part may make sense.

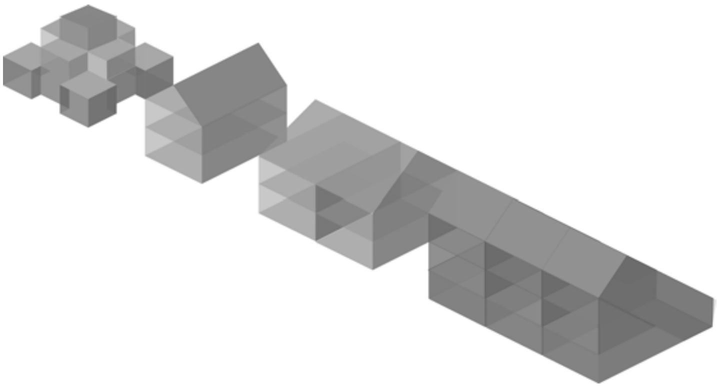


Fig. 182 Open-closed dwellings R=30m in P_{3km}

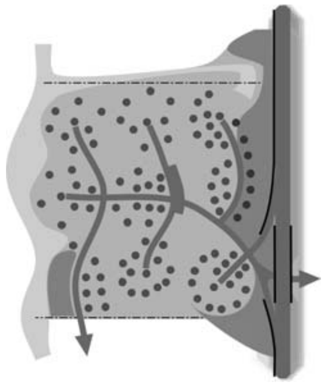


Fig. 183 Density R=1km

In *Fig. 183* , 100 R=30m dots, each representing floor space for 100 inhabitants (black) or jobs (grey), replace the neighbourhood circles of *Fig. 181*. High value and status in the North may protect the views of open land in the future (α_{3km}). Older people, just like family people with young children, do not want to live in very high or low densities. They need facilities in their neighbourhood ($\alpha\beta_{3km}$). Consumers look for high densities and facilities, but careerists may want to live in drive-in dwellings near the exits (β_{3km}, α_{1km}), or in representative environments (β_{3km}, β_{1km}). The question remains if the Southern neighbourhood in between both locations deserves a high density. The sketch of *Fig. 181* did not promise a high density. This shows how important even a very simple sketch as *Fig. 181* in the beginning may be, if it is passed and approved as a concept. In practice, you can refer afterwards to its implicit decisions.

Small components determining a large structure

In the previous paragraph, the ‘seclusion’ of dwellings R=30m, represented in *Fig. 182* is used to ‘fill’ a polarity that is operational at R=3km. Its relation with a gradually changing density, in a radius R=3km, may be relevant, but it shows also, how a sequence of small components may strengthen a much larger intended structure. This relation between different levels of scale, and their different characteristics, is something other than the relation between levels of scale, which is caused by the synpolar, orthopolar or counterpolar arrangements of *Fig. 145* on page 190. The polarities in *Fig. 182* do not play a role. Their overall characteristic of ‘seclusion’ does. To strengthen a large polarity, you should not only look for variables that are operational at the same scale *Fig. 74* on page 114.

The impact of curves

Deviations from a straight line will introduce many differences, at different levels of scale. This can be illustrated best at R=100m. In *Fig. 184* and *Fig. 186*, an area of 150 x 80m is filled with 52 two-story dwellings of approximately 5 x 9m, on average (ensemble-FSI = 40% with ample 70 parking lots). The dwellings, however, are clearly distinguished in ‘extravert’ and ‘introvert’ dwellings (see the divergent and convergent arrows of *Fig. 184*). These names do justice to any of their characteristics. The angle between the extravert lots is 10^{o}, and 20^{o} between the introvert lots to keep an approximately 5m dwelling width (see *Fig. 185*). Consequently, the introvert lots are twice the size of the extravert ones, in favour of their back garden and the width of their rear façade. They are substantially oriented towards the back side, leaving space for a kitchen in the rear. The extravert dwellings, however, will probably obtain a kitchen in the front.

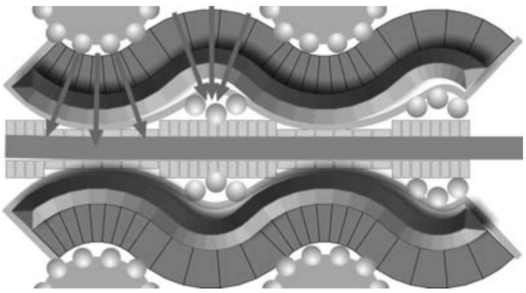


Fig. 184 R=30m Symmetric

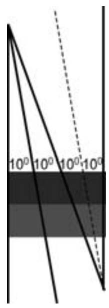


Fig. 185

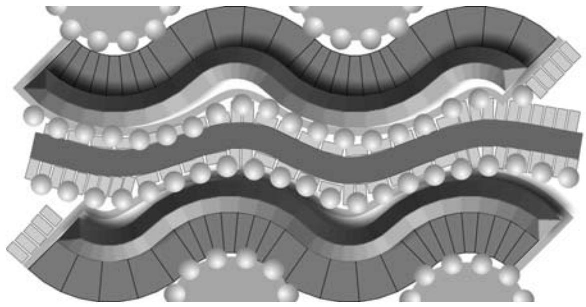


Fig. 186 R=30m Parallel

A curvature has substantial impacts on the public space, too. It diversifies the views on the façades, generating more surprises. The impacts, however, are different if the curvatures at both sides of a street are either symmetrical or parallel. In the symmetrical case (see *Fig. 184*), the street is articulated in wider and narrower parts, offering many possibilities to diversify its exits and inner furnishings. The introvert dwellings obtain a wider, but enclosed space at their front, but the extravert dwellings paradoxically do not obtain a view. They are directly confronted with their opposite neighbours (and their kitchens). In the parallel case (see *Fig. 186*) they obtain a view. In addition, the street may follow the curvature more easily, which reduces the traffic velocity spontaneously, but it becomes less diversified between the exits and inner parts of the street.

Extravert and introvert

The extravert and introvert character of buildings is a structural feature of divergent or convergent polarisation. It immediately obtains functional, social and cultural associations, which are illustrated through the difference between the external colonnades of a Greek temple, and the internal colonnades of an Egyptian temple or a Roman basilica.

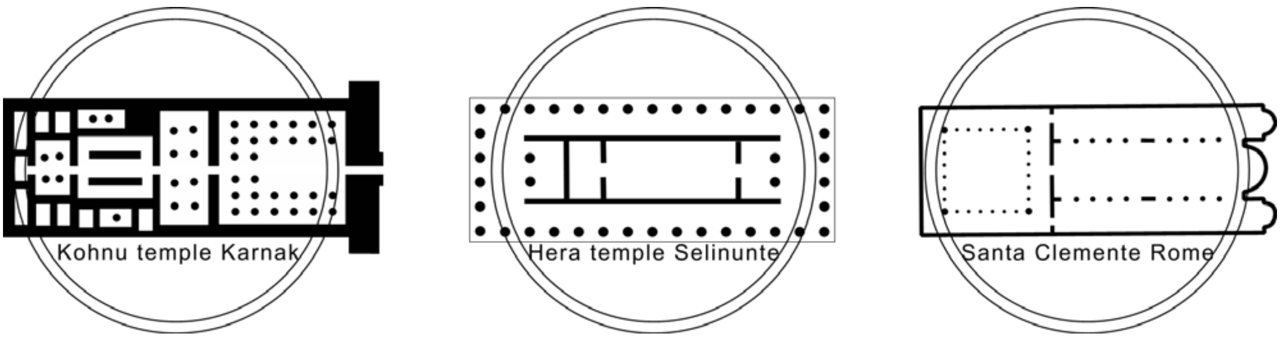


Fig. 187 Introvert Egyptian, extravert Greek, introvert Roman R=30m

Prototypical structures of landscape

Mountains, hills, and plateaus are divergent, while valleys are convergent. These are prototypical structures of extraverted and introverted landscapes. Decreasing altitude is followed by many variables, such as the accumulation of water, increasing temperature, vegetation and human use. At a larger scale, however, the lowlands, their harbours, cities and the sea are the open counterpart of inland highlands, with their valleys and villages. Its consequence is a difference of orientation on trade and agriculture. Invasions from the sea may have played an underestimated role in the origin of Western culture at the coasts of the Aegean Sea. Ionian invaders settled in the lower settlements, such as Milete, for outward trade, driving Aegean inhabitants inland. According to Herodotos[a], they killed the men, taking their daughters as their wives. If you take that seriously, this kind of connecting cultures may have happened more often, mixing an Appollonian and an older Dionysian culture. The remaining secret mystery cults may have seduced the busy, rational tradesmen into joining the seasonal grape harvest, or spring bacchanals in the mountains. The ecstatic Dionysian mysteries may have been a prototypical escape from urban life, as it lives on in our customary holidays and carnivals. It may have been the foundation for a continuous awareness of an alternative. One of its earliest representatives was Thales of Milete.

Structure and function

If a structure is *operational*, then it may *perform* a function in a larger structure. To know which function it performs, you must know the larger structure. If you ask me: “What is your function?”, and I answer: “Director!”, then your next question should be “Director *of what*?”. It could be a director of a one-person family, or a director of a large company.

If you want to remove a wall in your house, you must ask yourself whether it has a function in the bearing structure. The same counts for a road in a traffic system, a dike in the water system, a person in an organisation, a word in a sentence, and so on.

A function is necessarily part of a larger structure, but it also supposes a smaller operational structure that can perform that function. Thus, function is a connection between two levels of structure, and is consequently scale-bound. At any level of scale, however, you should distinguish the outward function *of* something, from the inward function *for* something. The next chapter restricts itself to location bound functions for a human population and its habitat, and the other way around. These locational functions may function directly population, or indirectly for their habitat. To put it the other way around, a population or a habitat has an ‘inward’ function for the performing structures

[a] Herodotus (440BC) *Histories 1 Books 1-2* (Cambridge Massachusetts1975) Harvard University Press Loeb Classical Library series

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6 Diversifying function

6.1 Environmental diversity enables functioning

Safety and choice
Environmental diversity provides alternatives that allow one to survive *risks* and freedom of *choice*.
This section demonstrates how any function *requires* some environmental diversity.
The reverse, human functions and facilities, *cause* changes of environmental diversity.
The next sections of this chapter concern functional diversification in its own right.
The history of human specialisation is a history of diversifying functions (sections 6.2 - 6.3).
But, the resulting facilities do not cover all the conditions for human life (sections 6.4 - 6.5).
Diversifying facilities may diversify the environment again, the process where it all starts.

Diversity functioning at R = 10^6m
People, animals and plants would not survive in a totally homogeneous environment. Imagine an equal distribution of two billion households of 4 persons at the surface of the Earth, equalised into a flat plane, without differences of altitude and temperature. Any household, then, would possess ¼ km^2 of surface. But, it would be covered by nearly 3km of water, and 50m of that water would be ice. It is clear that nobody would survive at the bottom of this world-wide sea. What would you have to do as a designer to make the world liveable? You should introduce the first difference by dividing land and sea, as described in Genesis 9. Suppose you decide there must be 70% less surface to concentrate the water. This surface you call ‘sea’, and the remainder ‘land’. Any household, then would possess 0.07km^2 , or 7ha, of land. But, it still would be covered with 50m of ice.
To store the ice at the poles, a second difference has to be added: a difference of temperature (Genesis 3). You are happy that there is a sun that the earth orbits around. Your planet circulates exactly at the right distance to provide water in different physical conditions, as ice, liquid and vapour. You are happy that the form of your planet provides different inclinations of sunlight, in order to make the required differences. If you keep the globe turning perpendicular to that direction in order to distribute the sunlight equally over the households every day, the resulting differences and changes of temperature will cause wind. Evaporation and precipitation would be distributed more equally through variations of temperature. To keep some water available on land subsequently requires some continental differences in altitude. Creating mountains and lakes provides local reservoirs of ice for long term storage, and fresh water that is used in the short term is distributed by rivers. Temperature and wind will be diversified more, by distributing the rain more randomly and equally for any household. I do not have to continue this thought experiment further to understand the function of environmental diversity at the largest relevant scale.

Diversity functioning at R = 10^{-6}m
At the smallest scale of life, the living cell shows an inconceivable amount of environmental diversity between its numerous membranes. The outer cell membrane enables rare physical-chemical processes to occur inside. They produce complex molecules and particles, which are assembled and partitioned in a sequence that would be very improbable outside the membrane. The particles move through numerous rooms, corridors and tubes. These environments have different concentrations of components, which are separated by

membranes. These membranes protect each part of the assembly against concentrations of disturbing components. The membranes take part in the processes themselves. Movement is caused by a delicate storage and exchange of energy, and differences in electric potential and concentration.

Diversity functioning at intermediate scales

The diversity in the images of Boeke and Morrison[a] (10^{-18} -10^{26}m) seem to appear between 10^{-6} and 10^{6}m. If you take millimetres and kilometres as the boundaries of our normal visual reach ('grain' r = 10^{-3}m and 'frame' R = 10^{3}m), then this resolution counts 6 decimals. Bacteria and individual cells (r = 10^{-6}) go beyond our daily visual range. Your direct awareness of environmental diversity starts with grains of sand and small insects. In the open field, it ends at 5km distance (horizon). At 10km distance somebody 5km behind the horizon can appear. But your scope, your 'window of attention', is smaller. If you take a closer look at the ground or a wider look at the horizon, you may start to divide the scene into a central component and its adjacent components (see *Fig. 111*on page 173 and *Fig. 65* on page 102). This thesis takes this smallest factor, 3, (one central, two adjacent) to distinguish diversities at different levels of scale. The normal visual range then counts 14 levels of visually distinguishable diversity: R = {0.001, 0.003, … , 1000, 3000m}. In the centre of this range, our R = 1m body is a miracle of diversity, which is caused by the organised specialisation of organs and cells in an organism. The function of environmental diversity from the cell to the organism as a whole, does not have to be explained here. The artificial environments, and those at the larger scales R = {1m … 10 000km} *outside* organisms, exhibit much less diversity as a diversifying challenge for design. It is the domain of ecology, technology, economy, culture and management. Let me first elaborate on the ecological function of environmental diversity.

Artificial environments

Levelling the surface and water-supply for agricultural purposes, in favour of one useful crop species, causes the loss of other species, and an increased risk for the remaining one. Farmers will complain in periods of both too much or too little rain. Different altitudes would have given differences of wetness and a smaller, but a more reliable and resilient yield. The same counts for other variables, such as too much or too little sunlight, temperature or fertilizer. Nutritious soils benefit from fast growing species, which oust others. They push slower growing rare specialist species away. Poorer soils may produce less, but they mainly produce more different *kinds* of species in the long term. Popular crops may become prey to massive diseases. Biodiversity may contain a reservoir of genetic material to replace them or to restore their resistance (potatoes[b]). In the past decennia, ecologists have discovered a remarkable diversity of plant species in towns (see *Fig. 189* and *Fig. 190*). *Fig. 191* shows the kind of urban environmental diversity that is apparently appreciated by wild plant species. *Fig. 192* demonstrates that these species are not merely the most common species. The unexpectedly high biodiversity in towns can be explained by the many environmental variables that diversify potential habitats on a relatively small urban surface. It is, however not always clear why wild plants 'choose' a location. Ecology still cannot determine all locally responsible environmental variables and values relevant for every species or even specimen. That is why any environmental diversification may be useful.

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[a] Boeke(1957)*Cosmic View*(New York)John Day
Morrison;Eames(1982)*Powers of ten*(New York, Oxford)Scientific American Books, Inc.
[b] Haan(2009)*Potato diversity at height*(Wageningen)University PhD thesis

Technology

If the raw material required for any technology would be totally dispersed and mixed with any other material on Earth, then its extraction would be a great problem. Plants capture and synthesize hydrocarbons from CO_2 that is dispersed in the air. They do this job with sunlight and water, if the sub-soil provides the right conditions, such as minerals and support. Any plant or tree requires different conditions. These conditions determine the possibility of obtaining different biological products, such as food and wood, that can be processed by different kinds of technology. These differences enable exchange, trade and local economic or technological specialisations. The hydrocarbons left from previous biological production, such as coal, oil and gas, are concentrated at specific locations, and can be mined economically. The *concentration* of minerals in general is a great thermodynamic advantage that is offered by the geological diversity of the Earth. But, the current technology of production and consumption mainly results in the *de-concentration* of raw materials as mixed waste. Technology mainly equalises the environment, and adapts it to currently common needs, with some exceptions, such as built-up areas that provide more diverse environments R = {10 … 3000m}. Transportation technology has made techniques foot-lose, except if the raw materials are difficult to transport, such as building materials. The best technical means survive, and they are dispersed world wide through communication. The remaining diversification of techniques is caused by specialisation, which is possible at any location. But, if raw materials, such as phosphate or rare earth elements, become scarce, then export quotas and cartels may again cause the emergence of alternative local technologies that are based on more locally available materials.

Economy

Environmental diversity has caused different kinds of production using local resources. Countries, regions, towns and even neighbourhoods have been specialised in particular kinds of agricultural and industrial production and services. But, technology (transport, greenhouses) made them more dependent on differences in wages than on environments. In a world market, a locally one-sided economy is vulnerable to changes. Homogeneous ecosystems in general are at risk in changing conditions. Thus, the diversification of regional economies have become accepted as a common strategy to reduce risks. But, economic diversification is not easy if a local economy depends one-sidedly on the export of raw materials, and if a low level of education hampers the importation of alternative technologies. Ongoing industrialisation of agriculture and specialisation in cities have caused a flow of unemployed people into the cities and into more developed regions and countries. Environmental diversity may regain an impact on economic diversity through export quotas of rare materials and increasing wages. If developing regions obtain higher wages, then this comparative advantage disappears (e.g. China). The priority will change into luxury goods, cars, housing, environment and perhaps nature. If the price of energy drops through the dispersed application of solar energy, then ongoing computerization and the development of robotics, may decrease the impact of wages once more. The more the capacities of people are replaced by computers, the less manual and routine work can be employed, and the more specialised jobs are needed. Smaller, more specialised enterprises (allowing productive experiments) may have opportunities everywhere. Cultural differences of their environment and changing encounters may determine their success more than wages and physical resources. Pedestrian areas are rediscovered as opportunities for such encounters (e.g. Broadway, New York). City marketing may stress its identity through its economic specialisation, and its historical, cultural and environmental differences from other cities.

Ecology

Londo (1997)[a] considered diversity as a *risk-cover for life*. Life has survived many catastrophes in its evolution. Its diversity always has provided a species, or within a species a specimen, that has been able to survive in changing conditions. Survival of the *fittest* presupposes a diversity of species and environments from which a few ‘fit’. Diminishing the diversity of habitats, then, undermines the resistance against catastrophes. From the 1.7 million species we know, we probably lost some 100 000, mainly because of the loss of fitting habitats. By doing so, we not only introduce ecological disasters, but we also undermine the resistance of life against disasters, such as climate change and epidemic diseases in homogeneous populations. The curve of *ecological tolerance* relates to the chance of survival of a species, a population or an ecosystem, in relation to any environmental variable, e.g. the presence of water. In that special case, survival can be ended through the water evaporating, or drowning (see Fig. 188). Imagine the bottom picture as a slope from high and dry into low and wet. Species A will survive best in its optimum. Therefore we see flourishing specimens on their optimum line of moisture (A). In the higher and lower areas, there are marginally growing specimens (a). The marginal specimens, however, are important for the survival of the species as a whole. In the case of long-lasting showers, the lower, too wet standing marginal specimens die, the flourishing specimens become marginal, but the high and dry standing marginal specimens start to flourish! Long-lasting dry weather has the same result in a reverse sense.

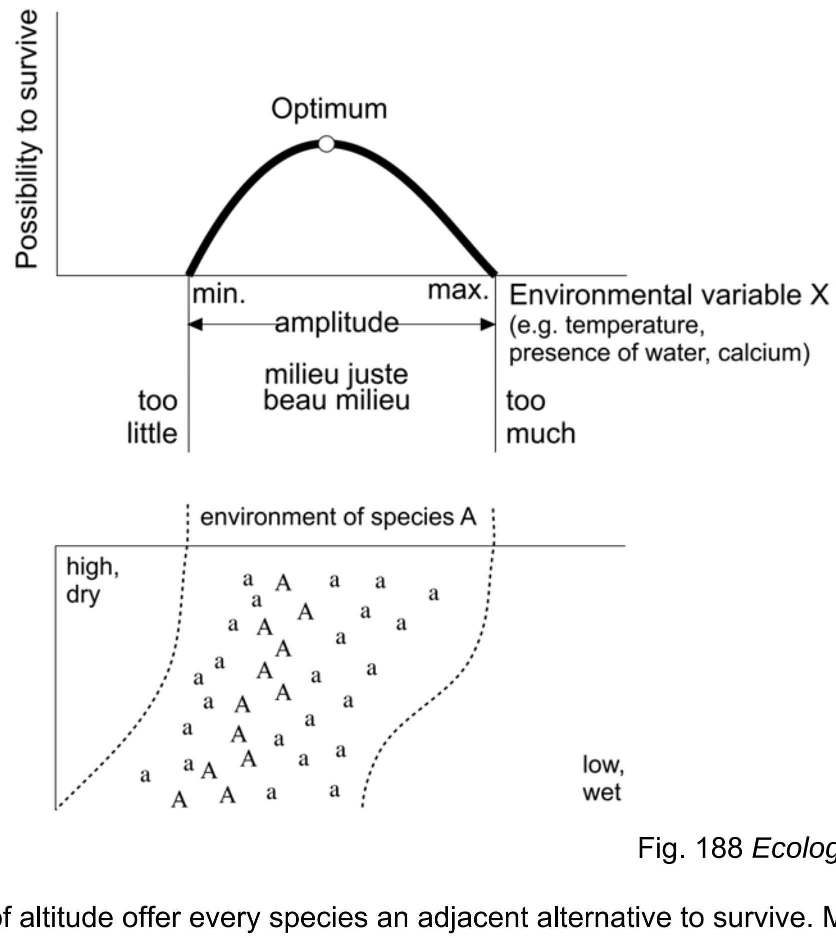

Fig. 188 *Ecological tolerance*

Differences of altitude offer every species an adjacent alternative to survive. Marginally surviving specimens take care of the survival of the species as a whole. A reservoir of unhealthy specimens, then, favours the survival of a species. The curve of ecological tolerance can be applied to many different variables other than the presence of water, at many levels of scale.

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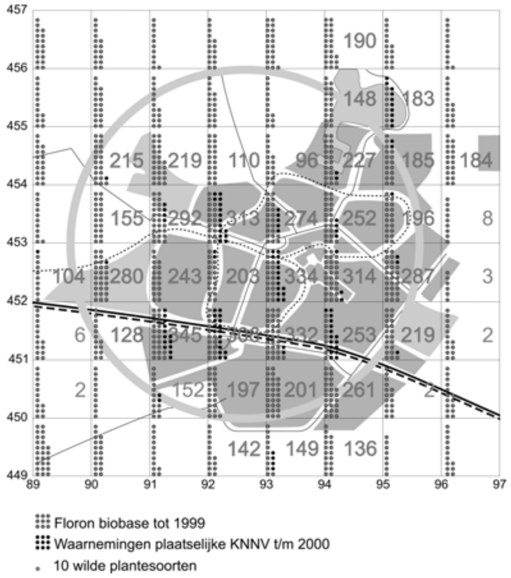
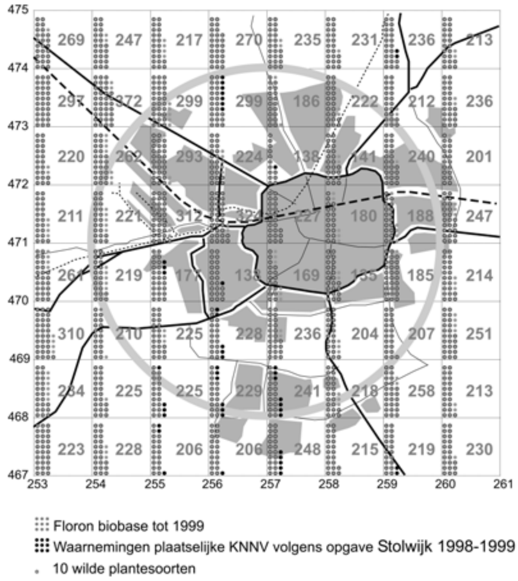
[a] Londo(1997) *Natuurontwikkeling* (Leiden) Backhuys Publishers



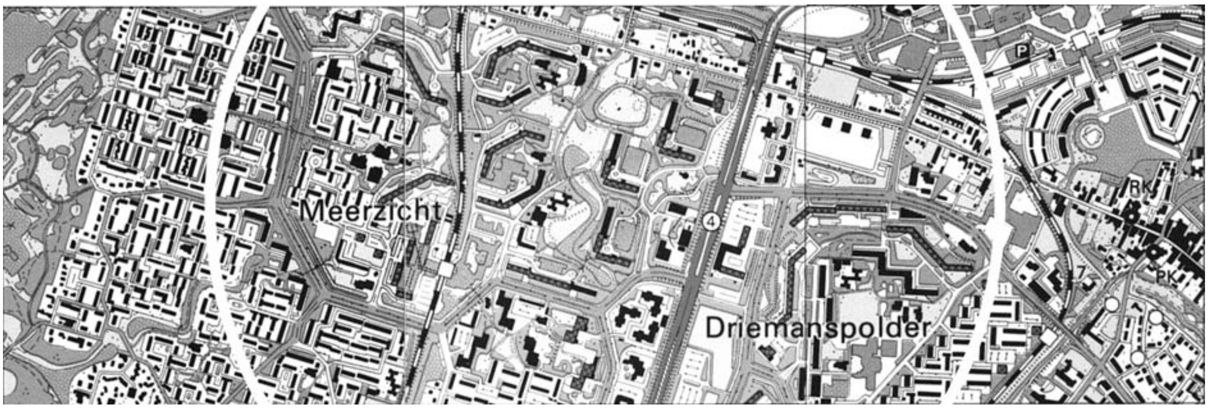
· = 10 wild plant species

Fig. 189 R=3km Zoetermeer 1999 More wild plant species than in its agricultural environment



· = 10 wild plant species

Fig. 190 R=3km Enschede 1999, the number is comparable to its forest environment



346 wild plant species 308 wild plant species 332 wild plant species

Fig. 191 R=1km Zoetermeer 1999 Number of species from the outskirts into the centre

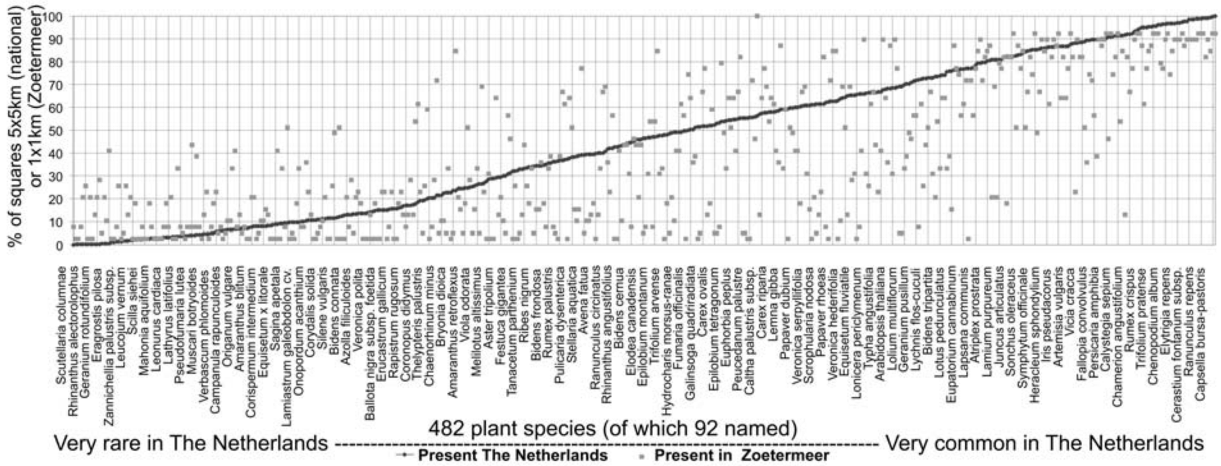


Fig. 192 National rareness of 500 urban plant species in Zoetermeer

Culture

Cultural differences within a city may be based on income (low-high), stage in the life cycle (young-old) and life style (e.g. consumers, careerists and familists, see page 139). Ethnic concentrations at R=300m may seem a problem in the beginning, but they appear to become attractive as an urban extension of the international economic network, or as a recreational destination. The quality of specific residential environments for different categories of people depends upon the scale of its internal familiarity and external contrast. Homogeneity of life style in a radius of R = 30m may give children at the age of 5 enough confidence to experience and explore differences in hygiene, nature, behaviour, possibilities to decide or to take initiative. A different kind of homogeneity at R = 100m may give children at the age of 10 the opportunity to explore other ways of life at R = 300m and cultures at R=1km (see *Fig. 19* on page 59). The composition of facilities of a district, a town or a conurbation (see *Fig. 205* on page 227) may represent a cultural diversity, which is emphasised by design and planning, and they are detailed at their boundaries. The kind of schools, shops and public space may be different. Repetition (r) and difference (d) may alternate at different levels of scale: the variety accord (see page 21) $d_{10m}r_{30m}d_{100m}r_{300m}d_{1km}$ will represent another urban environment than $r_{10m}d_{30m}r_{100m}d_{300m}r_{1km}$.

People need stimuli. Sensory deprivation[a] in space may cause a need for variation in time, and the reverse. The experience between too much and too little diversity should be balanced (see *Fig. 64* on page 102). Too much diversity can be reduced by selective attention, but too little diversity may cause boredom, and a search for adverse adventures. Busy people may choose simple interiors; people with boring work may choose an overload of ornaments at home. People in roaring times, such as the early Middle Ages, chose a simple Roman architecture; people living in the more quiet times that followed chose ornamented Gotic styles. The emerging money-economy, world-trade and the discovery of America introduced a more modest and recognisable Renaissance, which was followed by the exuberant Baroque period. This style compensated for the boredom of wealth. Classicism followed great revolutions, Jugendstil amused the new rich, and world wars introduced Modernism, which was followed by Postmodernism accepting more diversity. The main waves of culture alternate between tradition and and experiments.

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[a] Proshansky;Ittelson;Rivlin(1976) *Environmental Psychology 2nd Edition. People and his Physical Setting* (New York) Holt, Rinehart and Winston

Management and government

Mass production requires an efficient equality of minds and material. Innovation requires an ability to cope with a diversity of minds and possibilities. The management laws of mass production applied to teams with an innovative task may be productive, but they will mainly produce what can be expected. A management of production elaborates what is already known. It cannot go beyond the imagination of management, which is enclosed in its targets and regulations (Meno's paradox[a]). Innovation often hides in the details, the side-roads that open up landscapes that are not foreseen in any targets and regulations. It is often the product of individuals driven by curiosity beyond citations. You may conclude, that a laissez-faire style of management would be most appropriate for innovative teams, but that is not the case. On the contrary. A production management shaping the conditions for production even may have more periods of laissez-faire than innovation management. Innovation requires continuously and actively shaping new conditions and possibilities, and collecting new minds and resources. It requires a multitude of initiatives, but only a switch into production-mindedness if something is found that has market value. It requires the acceptance of many failures. Government, however, is a kind of management, taking care of conditions at a larger territorial scale and for a longer time span. Laissez-faire governments may produce environmental diversity at the smallest scales, but producing or protecting diversity at a larger scale requires initiatives, planning and design. Regulation by orders and prohibitions may produce homogeneity, but shaping conditions may produce diversity. Government is a scale-sensitive balance of laissez-faire and initiative. Different environments have resulted in different kinds of government, and the reverse. A diversity of environments avoids substantial risks. Applying different strategies of territorial development provides alternatives in changing conditions and exchange of experience. China accepted two Special Administrative Regions (Hong Kong and Macau), and several special economic zones. The territorial diversification of laws and treaties is usual in the task division of a nation, its states, provinces and municipalities. It is based on local tradition, culture, economy, technology and ecology. It exploits the possibilities of different social contexts and physical environments.

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[a] Plato (380BC) *Laches Protagoras Meno Euthydemus* (Cambridge Massachusetts 2006) Harvard University Press Loeb Classical Library series page 299

6.2 Functions

Outward and inward functions

Dwellings, schools, energy plants and so on, are *structures* with a *function*, in a larger whole. They are called 'functions', but I name them 'facilities'. 'Function' indicates their 'working'. Facilities *have* a function, and this function is two-sided. It contains their *outward* effect or performance on a larger whole, and the *inward* effect of the larger structure, keeping them operational. This distinction between outward (bottom-up) and inward (top-down) function will prevent a confusion of tongues. Outward and inward functions require different approaches, such as counting outward profits for the whole or inward profits for the parts. The difference is comparable to the subject of study in micro- and macro-economics, but in technology and design you may meet that difference at any level of scale again. At any level again the parts have a function for a larger whole, and this whole has a function for its parts. Both functions include positive (eufunctional) *and* negative (dysfunctional) effects. An energy plant produces electricity for the human population, but it may have negative side effects on its environment. A municipality offers you infrastructure and protection for your business, but it also imposes restrictions and you have to pay taxes. Any outward supply meets inward demands and conditions. The larger spatial, ecological, technical, economic, cultural and organisational structure of a human population and its habitat conditions its facilities. This inward function enables and restricts *specialisation*. A human population divides its tasks between its facilities at different locations of its habitat. A municipality may decide to build an industrial estate. A population may change its tasks, in order to balance the supply of facilities. A school may obtain a different educational programme if the society changes its requirements. In the next section, I will elaborate the inward function first. But in practice, they develop simultaneously, reacting on each other in an alternating sequence.

A history of specialisation

Substantial specialisation began approximately 10 000 years ago due to the invention of agriculture (Neolithic Revolution). It bound former hunters and collectors to a location. The concept of defended property, labour and delay of benefit stabilised. The bond between people and their land led to the need for people to exchange goods. Agriculture soon resulted in a surplus production that could be exchanged between people. Beyond agriculture, the surplus enabled specialised crafts and trades with new techniques and products. The development of specialised techniques enabled the use of stone, bronze and iron. Central market settlements emerged. Tradesmen, captains of barges and soldiers could survive through trade and providing services, without growing their own crops and cattle. Their facilities replaced former domestic functions, such as production, education, health care, religion, jurisdiction or defence. Money (the delay of benefit) extended the market. Centralised power exacted by paid soldiers resulted in great empires concentrating the agricultural surplus in defended towns.

Capital, a replacement of human power

Natural energy sources replaced human and animal power in Holland (wind), in the United Kingdom (coal) and in the United States (petrol), successively in the 17th, 18th and 19th century. Natural energy sources led to the centralisation and increased efficiency of production. The steam engine, improved by Watt, introduced the Industrial Revolution. This innovation was followed by the invention of the petrol engine by Benz. Industrial production ousted dispersed industry in villages and still autarkic farms with extended families in local communities. Rural people were forced to sell their labour to the growing industrial companies in rapidly growing towns. The development of know-how and science resulted in an explosion of new technologies and specialisations. Newly invented products changed consumption from largely driven by demand into substantially driven by supply. Companies may de-concentrate their activities, in order to come closer to the different consumer markets, but others may concentrate close to their resources, labour or suppliers.

The size and form of towns changing by function

The urban surface of cities did not only increase in regards to their increasing populations (see *Fig. 193* 1 and 2), but also through increasing prosperity (3), which required the development of more facilities. People began to use more and more space, while at the same time, urban density has become lower. *Fig. 193* shows both kinds of growth, roughly worked out, in Europe. The same process occurs in cities throughout the world.

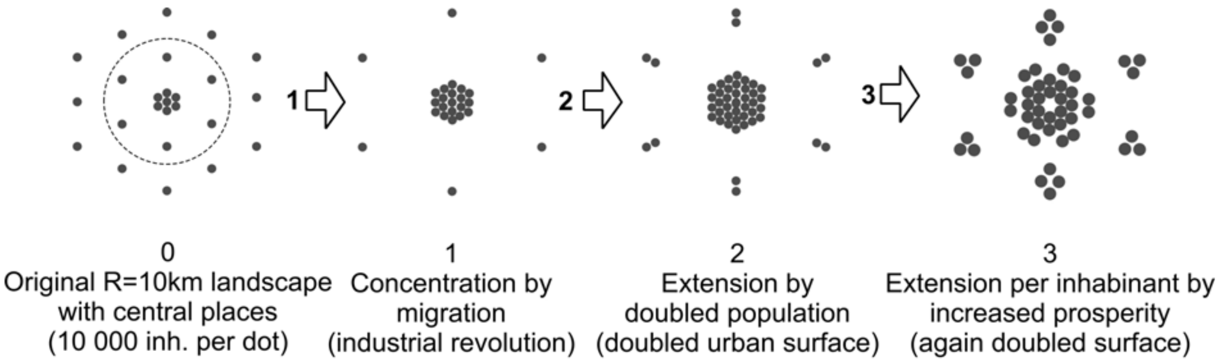
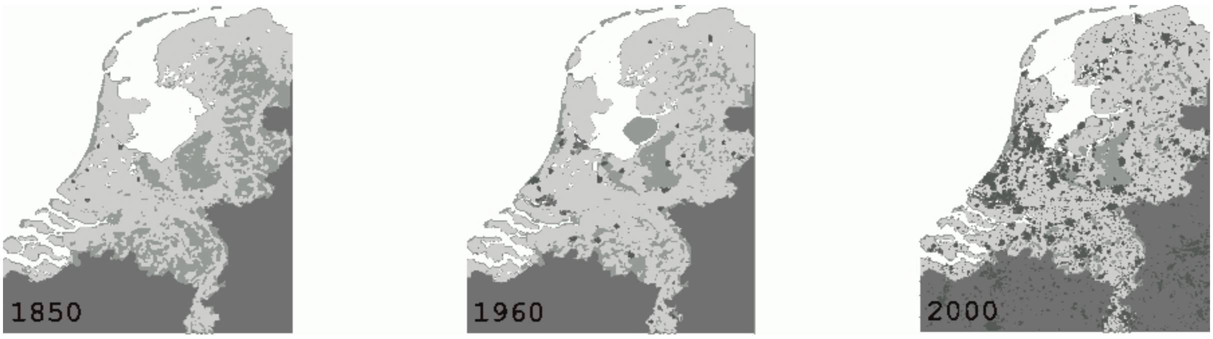


Fig. 193 Three processes increasing the urban surface *R=10km*

Fig. 194 shows two changes in the Netherlands: an increasing population migrating into the cities during the industrial revolution after 1850, and a growth of the economy after 1960. Both developments have substantially increased the urban surface within a century or two, but elsewhere this phenomenon occurs within a decade, threatening the economic balance between town and country.



3 million inhabitants 12 million inhabitants 16 million inhabitants

Fig. 194 The urban history of the Netherlands[a]

R=100km

[a] Based on images made by dr. Scheele(1988), University of Utrecht

For example, China struggles with a declining agriculture, and the threat of insufficient food production for the populations in its exploding cities (see *Fig. 195* - *Fig. 200*).

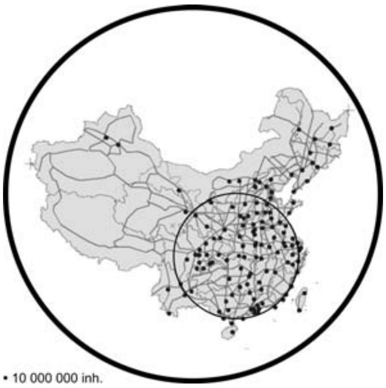


Fig. 195 China inhabitants[a] *R=3000km*

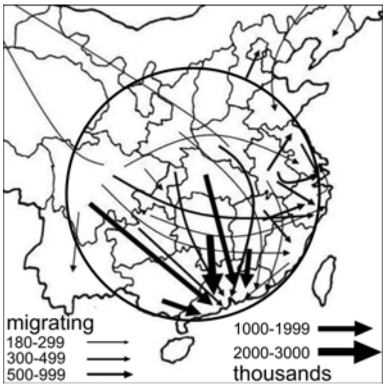


Fig. 196 Migrations 1995-2000[b]

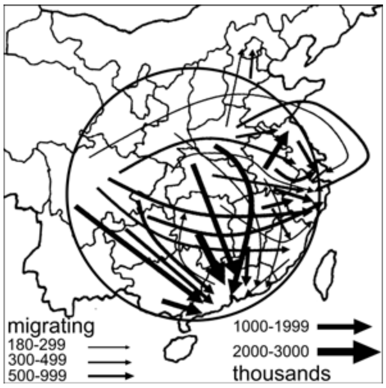


Fig. 197 ~ 2000-2005[b] *R=1000km*

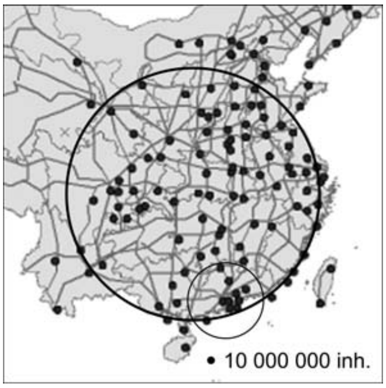


Fig. 198 R=1000km

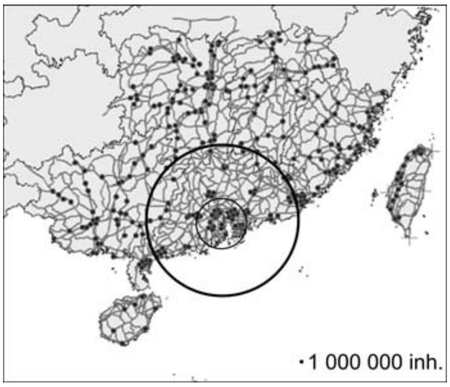


Fig. 199 R=300km

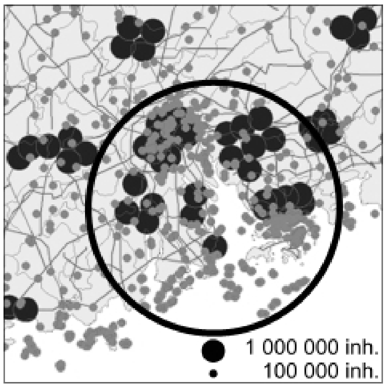


Fig. 200 R=100km

[a] Liang(2010)*Spatial Transformation Pearl River Delta*(Delft)TUD PhD report
[b] Chan(2008) *Internal labour migration In China. trends, geographical distribution and policies* (New York) Population Division, Department of Economic and Social Affairs, United Nations Secretariat

6.3 Inward functions

Ecological specialisation enables social organisation

Any population has a habitat, a dispersion in *space* with *ecological* connections, and a *technique* to exploit them. Human populations occupy different habitats. They may specialise in different techniques (harvesting, cattle breeding, fishing). Specialisation based on different techniques enables people to exchange their products at a market (an *economy*) to fulfil the needs they can no longer fulfil themselves. A market enables the emergence of shared suppositions (about other people, their products, their behaviour, their demand and expectations). The set of shared suppositions in a population is its *culture*. Culture disperses techniques of specialisations through education, and an awareness of a larger spatial, social and even religious whole, in which you are supposed to function. Specialisation makes you vulnerable if you cannot trust everybody in an enlarged society. It requires a common infrastructure with regulations that you cannot exact on your own. A set of shared suppositions enables an *administration* that registers and defends your rights, and takes care of requirements that you cannot buy yourself. 'Space-time', 'ecology', 'technology', 'economy', 'culture' and 'administration' as they are italicised above, are thus conditioned by people's specialisations.

Specialised facilities

Around the market square of old towns you may recognise 'economy', 'culture' and 'administration' as a '*trias urbanica*'[a] (see *Fig. 201*).
Towns may have their origin or specialisation in one of these three facilities.[b]

Specialisation	**Urban facilities**
Administration	castle, palace
Culture	church, cloister, schools
Economy	market, shops, small businesses, dwellings

Fig. 201 Trias urbanica in the Middle Ages

In modern towns, a further subdivision[c] is recognisable in their buildings (see *Fig. 202*).

	Specialisation	**Urban facilities**
Politics	legislative power	town hall
	legal/administrative	law court/government services
	executive power	police station, prisons, military facilities
Culture	religion/ ideology	churches, monuments, signs
	art/science	museums, institutes, libraries
	up-bringing/education	schools
Economy	Production	companies, offices
	Exchange	infrastructure, shops, banks
	Consumption	hospitals, leisure facilities, parks, dwellings

Fig. 202 Social and urban specialisation recognisable in modern towns

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[a] George(1964) *Précis de géographie urbaine* (Paris) Presses universitaires de France
George(1966) *Geografie van de grootstad, het probleem van de moderne urbanisatie* (Utrecht / Antwerpen) Het Spectrum
[b] Brugmans;Peters(1910) *Oud-Nederlandse steden 1 en 2* (Leiden) Sijthoff
http://team.bk.tudelft.nl/Publications/2012/Literatuur/Brugmans(1911)1.pdf
http://team.bk.tudelft.nl/Publications/2012/Literatuur/Brugmans(1911)2.pdf
[c] Jakubowski(1936) Der ideologische Ueberbau in der materialistischen Geschichtsauffassung (Danzig 1974)
Parsons(1966) Societies : evolutionary and comparative perspectives (Englewood Cliffs, N.J.) Prentice-Hall
Parsons;Toby(1977) The evolution of societies (Englewood Cliffs; London) Prentice-Hall
Montesquieu(1748) De l'esprit des lois (Geneve http://www.gutenberg.org/ebooks/27573) Barrillot

Inhabitants required per facility

From the approximately 300m^2 gross urban area per inhabitant in the Netherlands in 2000 A.D., one half were covered by facilities. Residential areas, including daily facilities, covered the other half.[a] For example, the urban surface of Amsterdam increased in regards to its population until 1960 (see *Fig. 203*), but afterwards it increased *per inhabitant* through an increase in prosperity (see *Fig. 204*).

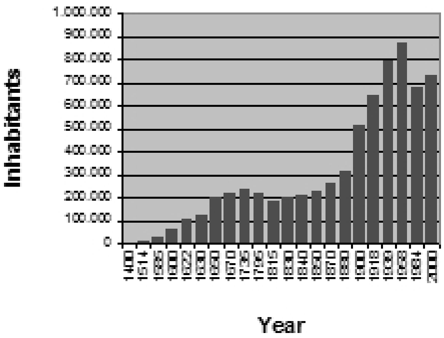

Fig. 203 Amsterdam population[b]

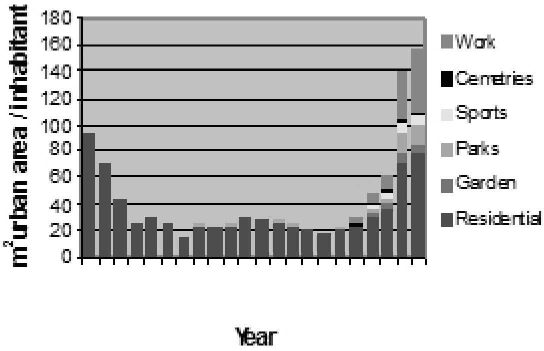

Fig. 204 Urban surface per inhabitant[a]

The development of technology and infrastructure enabled the concentration and de-concentration of specialised facilities. The number of inhabitants served by one facility mainly increased, but also sometimes decreased. For example, the 16 million inhabitants of the Netherlands in 2000 A.D. supported one national, 12 provincial, and approximately 500 municipal governments (in 2010 fast decreasing into 400). On average, there are approximately 16 million inhabitants served by the national government, 1.3 million inhabitants served by each provincial government, and 30 000 inhabitants served by each municipality. To obtain a rough impression of what kind of facilities you may expect in a neighbourhood (300-3000inh.), a district (3000-30 000inh.) and so on, you may calculate the average bearing surface for any facility. Simply divide the national number of inhabitants by the number of each facility (see *Fig. 205*). The distances named in *Fig. 205* are the nominal radiuses R within which you may expect these facilities.[c] You may check if you can find the named facilities in your neighbourhood, district and so on within the indicated radius.

Concentration at some levels of scale

Older figures with different, and thus incomparable, categorisations show discontinuities with accumulations at distinguishable levels of scale. The general categories in the left part of *Fig. 206* are specified into more specialised subcategories in the right part. For example, the general category ‘swimming pools’ (available for approximately every 20 000 inhabitants) in the left graph is subdivided in the right graph as ‘indoor swimming pools’ (50 000inh.), ‘outdoor swimming pools’ (60 000inh.) and ‘mixed swimming pools’ (70 000inh.)[d]. More general categories may be more useful to understand the spatial consequences than further specifications. The mutual differences between swimming pools are less relevant than the difference between swimming pools and shops. This example shows how categorisation may influence the image substantially.

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[a] http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=37105&D1=1-8,13-16&D2=0,2,7,9,l&D3=0,46,96&HDR=T&STB=G1,G2&VW=T

[b] Figures based on data in: Haupt;Berghauser Pont(2005) *Spacemate©the spacial logic of urban density* (Delft) Imprint: DUP Science

[c] The nominal radius is calculated assuming an urban land use of 300m^2/inhabitant, but this number varies. If 1000 inhabitants in the East of the Netherlands use 400m^2 and in the West 200m^2, then the real radius would be 350m and 250m respectively, but these distances still fit well within the tolerance of the nominal R=300m (see *Fig. 17* on page 52).

[d] 1/5 + 1/6 +1/7 ≈ 1/2

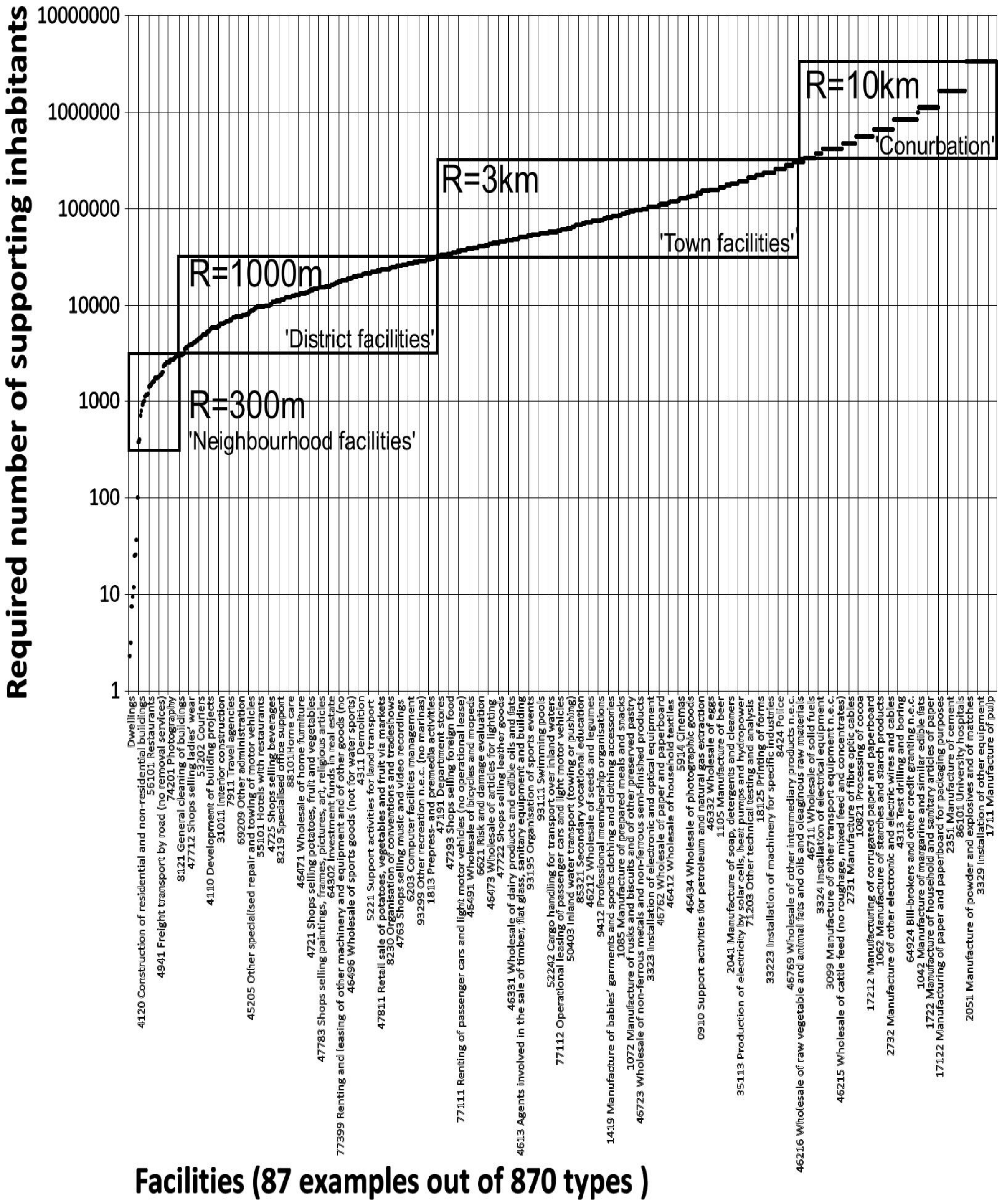
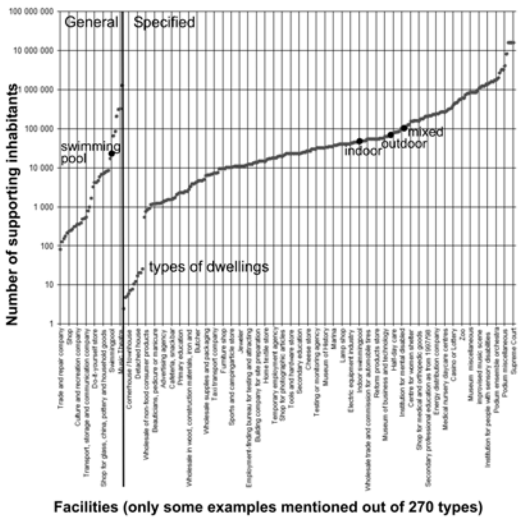
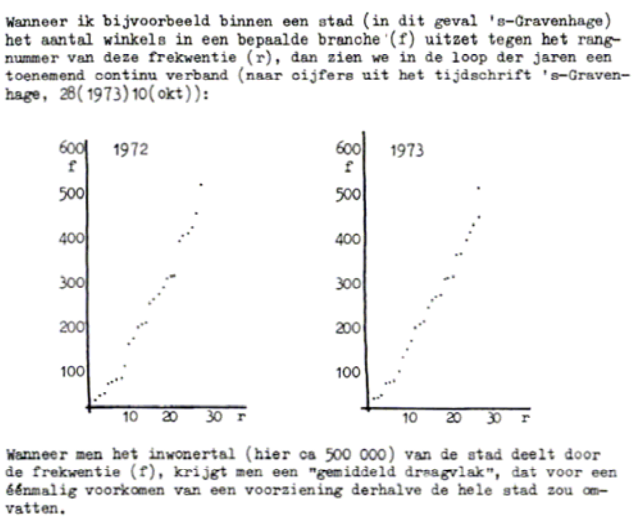


Fig. 205 The average number of inhabitants required for each of the 870 facilities distinguished[a]

[a] Most of these numbers were derived from the database of the Dutch Central Bureau of Statistics (CBS) in 2012. The ranking, however is very dynamic. It changes per year. The graph is intended only to give an impression. In the graph every thenth facility is named at the horizontal axis, the others are specified in http://team.bk.tudelft.nl/Publications/XLS/06aLiving.xls .




Wanneer ik bijvoorbeeld binnen een stad (in dit geval 's-Gravenhage) het aantal winkels in een bepaalde branche (f) uitzet tegen het rangnummer van deze frekwentie (r), dan zien we in de loop der jaren een toenemend continu verband (naar cijfers uit het tijdschrift 's-Gravenhage, 28(1973)10(okt)):

Wanneer men het inwonertal (hier ca 500 000) van de stad deelt door de frekwentie (f), krijgt men een "gemiddeld draagvlak", dat voor een éénmalig voorkomen van een voorziening derhalve de hele stad zou omvatten.

Fig. 206 National discontinuities 2000

Fig. 207 Urban discontinuities 1973[a]

In my earlier thesis of 1978, I found a remarkable difference between 1972 and 1973 in the statistics of shops in The Hague. The frequency (f) of any kind of shop (r) from the 30 ranked categories in *Fig. 207* still showed accumulations around 100, 200, 300 and 400 of the same kind of shops in 1972. The Hague had approximately 500 000 inhabitants.
The accumulations in 1972 thus supported different combinations of approximately 5 kinds of shops for 5000, 2500, 1700 and 1250 inhabitants respectively. Between a neighbourhood~ and a district centre, each could have a different composition.
A year later, however, it had become more difficult to choose the right level to concentrate the shops. The largest gap in the graph appears at f=300 (500 000/300 ≈ 1700 inhabitants), apparently enough for 10 different kinds of shops in 1973.
In 2010 (see *Fig. 205*), a modern supermarket requires 3000 inhabitants.

A diversity of sizes

Both inhabitants and facilities require more and more floor space, private yards, gardens and public (parking) space. This results in sprawl, a larger distance between inhabitants and facilities, which is compensated by internet shopping. The floor space of dwellings is rather well monitored, but the surface requirements of facilities are very different per facility, and they change every year. Private advisors keep their precious knowledge behind, and it is difficult to obtain an overview. General categories such as parks, swimming pools and shops obviously require different classes of floor space, but their economic categorisation is not based on such a diverse and changing property such as size.

A diversity of forms

Suppose you have to design a shopping centre with 10 000m^2 business floor space (the size of a large district centre or a small town centre). There are two alternatives then: extended along a district road or compact in a covered shopping centre. Many parameters will determine your design[b], but in both cases the spatially most influential parameter appear to be the depth of the shops. Compared to the result with 10m deep shops (see *Fig. 208*), a solution with 20m deep shops (blue in *Fig. 209*) substantially reduces public space and walking distances (into the red parking spaces or the yellow stops of public transport). Shopping centres may become outdated by the internet, but building depth of residential areas or any other built-up area has the same impact.

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[a] Jong(1978) *Milieudifferentiatie; een fundamenteel onderzoek* (Delft) THD Bk Thesis
[b] See the downloadable interactive computer programme http://team.bk.tudelft.nl/Publications/XLS/06aLiving.xls .

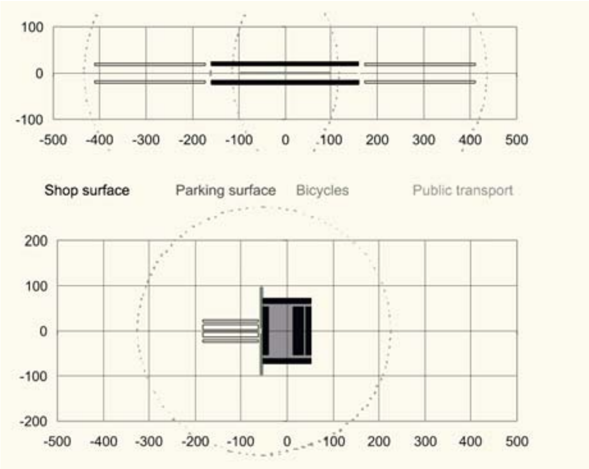

Fig. 208 10 000m² floor space 10m deep

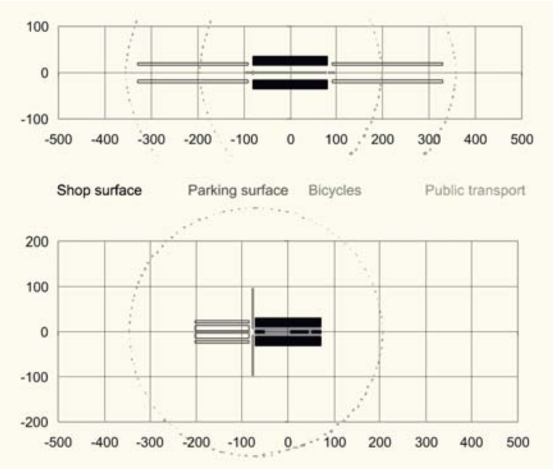

Fig. 209 10 000m² floor space 20m deep

Environmental effects

The problem of having sufficient parking spaces, however, remains a challenge anywhere, particularly if you choose to develop narrow and deep buildings in order to save public space. In *Fig. 208* and *Fig. 209* I have chosen for 1 parking lot per 15m² floor space for cars 5 x 2,4m (1600m parking length drawn red) and 1 cycle place 2 x 0,6m per 20m² business floor space (300m parking length drawn green). This is nearly a 2km road length for parking if it is not folded up into a building.
Around industrial or traffic facilities, you may avoid destinations that are vulnerable to noise, air pollution, smell nuisance and so on (outward zoning), or you may avoid facilities that are around vulnerable (residential) destinations (inward zoning). Both cost space, or reduce its use potential. Environmental effects affect the primary physical conditions of specialisation itself: space, time, ecological resources and the tools and techniques required to exploit them.

Space-time conditions of specialisation

The inward functions mentioned above are visible on a map as social facilities and buildings for government, culture and economy (see *Fig. 201* and *Fig. 202*). On page 225, however, space, ecology and technology have been mentioned also as conditions that facilitate specialisations. They may be less recognisable on the map, but if they are lacking they appear to be even more basic. If there is not enough space, if the resources are not available, or the technology is inappropriate, then any specialisation will fail. In general, separating functions (specialisation) seems to save time at the cost of space, while combining functions the other way around takes time but saves space. If you separate cooking and eating, separating your table into a kitchen unit and a dining table, then it will save time, but it will take more space. If you give walkers, cyclists and cars their own lane on the road, then it will take space, but it saves time (and even 'life time' if you take casualties into account). If arts and crafts move from residential areas into an industrial estate, then the increased efficiency of work saves time, but it requires space. There must be a relation between specialisation and our space-time budget, but the rule of saving time by specialisation at the cost of space suggested above is too simple on its own. A canteen in a company may *save* time, but that combination of functions within a building may *cost* space, *violating* the suggested rule. *According* to the rule, however, sharing a restaurant with other companies in the neighbourhood may cost time saving space. The way time and space are measured as lost or saved and the levels of scale involved must be determined deliberately, in order to obtain a valid ´space-time law´ of specialisation. I still have not succeeded in finding such a method, or a reference that describes it.

Ecological conditions of specialisation

Any population is ecologically connected to its habitat in different ways. The diversity of these connections and the diversity of the resulting resources may lead to different tasks. The other way around, specialisations may emerge if the same resource is used differently by different people. Both the diversity of people and the diversity of their habitat are ecological conditions for specialisation. If all people were the same, living in the same non-diversified habitat, having the same connection with their habitat, then there would be no specialisation. It would be either a world of extreme competition with survival of some accidentally fittest or a world of isolated individuals with no expectations from each other because nobody has to offer anything that anyone else may need. Fortunately, this is a frightening theoretical case, but it clearly demonstrates diversity as the core of ecology and ecology as a primary condition for specialisation beyond space and time. The next question then is, which *kind* of ecological diversity determines the inward diversity of functions within a population or its habitat? I will postpone the development of an answer to the philosophical question of whether you can speak about ‘kinds of diversity’ at all, until my next publication. It is a mind-bending question, because any categorisation you may propose, already supposes the differences between the categories chosen. The question, however, demonstrates that to explore diversity, any distinction between ‘kinds of diversity’ is fundamentally arbitrary, limited by the categorising nature of words and language themselves. Ecological conditions which enable the specialisation of populations and their habitat, are spatial or temporal. Temporal conditions are differences between seasons, day and night, the hours of the day and so on. These differences are called ‘changes’. The *amount* of change may differ itself in space, but not the other way around. Time then supposes space, not the other way around. Space is the primary container of difference *including* change. It is filled with matter, energy and information and all of them may differ. Outdoor and indoor conditions differ in light, temperature and humidity, enabling different functions and specialisations. Land and sea, forests and meadows, urban and rural ecosystems enable different functions and specialisations. Many ecological variables enable the technical *possibilities* of function: sun, energy, wind, noise, water, earth and life, as well as people, can be considered environmental variables.

Technical conditions of specialisation

During 3 million years, the natural environment of the Earth has offered approximately 3 million people direct resources for all their human functions. Since approximately 10000 years, however, the world population has been increased nearly with a factor 3000 into the current population. There is no way back to ´Nature´. A population of the current 7 billion or the near future 9 billion people can no longer survive without a multitude of artificial tools and facilities. The current population requires tools enabling techniques of mass extraction, selection, transformation and assembly to survive. It requires transport facilities in order to collect the distributed products of these locally specialised techniques and to distribute them amongst the intermediate producers and final consumers (see *Fig. 178* on page 209). These are the technical conditions of any specialisation. Their application requires specialised skills and knowledge of these tools and techniques. The history of mankind cannot be understood without the under-laying history of its discoveries and inventions. There may be some animals that make tools, but the unique ability to overlook a larger sequence of actions, of which only the first can be done immediately and only the last will satisfy the actor (see page 15), enabled the human population to survive and grow to its current size. Its survival now depends upon exploiting the natural resources through the application of artificial tools and techniques in many parallel sequences by many specialists. Without the these technologies of production and transportation, the actual division of economic, cultural and managerial tasks would be unimaginable.

6.4 Outward functions

Going out and coming home

The dwelling, with its many kinds of use, is still the most multi-functional urban facility.
The archetype of a dwelling is the autarkic farm. In these farms, the different generations of an extended family were united in a common household for many millennia after the Neolithic Revolution. "The more isolated a system is, the more totipotential it must be."[a] This household, however, gradually handed over more and more functions to the surrounding, increasingly specialising society.[b] Manufacturing tools, clothing and buildings could be farmed out in exchange with home-grown products, which saved time and increased production rates. Medical, religious and educational tasks were removed from the scope of home businesses, in order to be continued more efficiently in hospitals, churches and schools. Governments took over the tasks of defence and jurisdiction. Finally, even the major part of productive labour was replaced into locations outside the dwelling. The family household thus lost many integrated functions, and consequently its structure. It reduced the necessity of a certain size (say 30 people). The members of the family became hunters and collectors again, searching for personal fulfilment of more individual needs outside their home. This development of the household has had far-reaching consequences for the management, culture, economy, technology, ecology and use of space-time in an urban society. The transition into the modern family is experienced most radically by immigrants from rural societies into the city. Parents with an agricultural background must cope with children becoming hunters and collectors in an unfamiliar urban jungle.

Increasingly interfunctional activities

An economy with specialised functions requires a more formal organisation of activities than the prototypical autarkic farm. This community was operated through informal social control. It allowed the easy take over of diverse but relatively simple tasks, which were learned through daily practice from childhood onwards. Your tasks thus may gradually change according to your age, appearance, and changing capacities and talents. The activities in an extended cooperating family fulfilled personal needs and inclinations more directly, and were more often ‘functional on their own’, or ‘solo-functional’, as I will call them. Eating, sleeping, and leisure are examples of solofunctional activities that directly fulfil needs.
Paid employment requires more strict appointments than the task divisions in an extended family. An economy with advanced specialisations requires less autonomy and more written contracts for well-described, homogeneous performance, which are proven by educational certificates. Employment activities do not directly fulfil personal needs. These activities only make sense within a longer series of activities. Therefore, I will call them ´inter-functional´. Travelling or moving (if it does not have any leisure or sightseeing function) is a clear example of an interfunctional activity. The fulfilment of personal needs, the final reward, is substantially postponed through time consuming interfunctional activities that must be performed before attaining a reward. Money thus is the certificate of a postponed reward. The reward can then be chosen more freely later. This freedom of spending may compensate the lost kinds of former freedom.

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[a] Miller(1965) *Living systems* (Behavioral Science)10 p 193-237, 337-378, 380-411
[b] Mayntz(1955)*Die moderne Familie*(Stuttgart)Ferdinand Enke Verlag

Activities and facilities

Multi-functional facilities provide more possibilities for *solofunctional* activities than mono-functional facilities. *Mono-functional* facilities mainly facilitate *interfunctional* activities. This may be interpreted as a negative relation between space and time (see *Fig. 210*). The main stream of modern functional diversification (thick arrows in *Fig. 210*) is recognisable as a specialisation of the activities, and a segregation of the facilities where they take place. There are, however, also minor developments in the other direction. Sometimes, different activities are integrated and combined in more multi-functional facilities (thin arrows in *Fig. 210*). The development of information technology enabled more work, shopping, education, culture, care and leisure at home. If this development continues, then the residential environment may become more important.

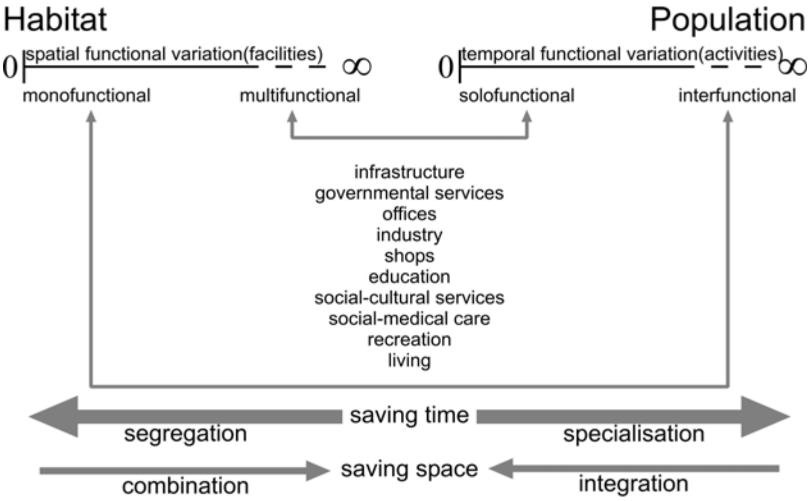

Fig. 210 Urban functional variation …

	1970[a]	1970[b]	1970[c]	1983[d]	2000[c]
infrastructure	70	14	52	91	71
government	1	1		1	
offices	2	1		3	
industry	12	10	18	67	83
shops	6	2		2	
education	6	1		6	
cultural	5	4		8	10
care	3	2		4	
recreation	45	30		64	56
residential	60	145	145	137	139
	210	210	215	383	359

Fig. 211 .. m^2/inhabitant

It is difficult to retrieve information concerning the surfaces involved. Changing categories of land use statistics in the Netherlands made them incomparable through the years
In addition, the distinguished categories are not very suitable to observe functional diversification. *Fig. 211* shows an increase of urban surface per inhabitant, but a substantial part of the counted industry and recreation may be located outside the urban area. The urban area/inhabitant thus may approach the earlier mentioned $300m^2$.

Intensity of use

The hr/m^2 *intensity* of use of facilities may determine their profit, but it is difficult to determine. Dividing the hours spent for specific activities by the surfaces involved, delivers the intensity of ground use, but these data sets (if available) may be categorised differently. *Fig. 212* is my last (1986) attempt[d] to tune different categories of time and ground use. The resulting data are not very reliable, but if you give them some credit, the surface of shops appeared as most intensely used. It is remarkable that the surface in and around the dwellings are much less intensively used. Even if the figures of total time and surface are not very precise, the average intensity is low. If the average intensity is indeed $41hr/m^2$ per year, then an average square meter in the Netherlands remains unused during the rest of the 8760 hours of the year. This may be an adequate explanation for the surprising observations of wild life in towns.

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[a] Angenot(1970) 1) Algemene planologie. 2) Sociogenese. 3) Stedelijke elementen. 4) Methoden en technieken 5) Verkeersonderzoek (Delft) THD

[b] Jong(1978)*Milieudifferentiatie*(Delft)THD PhD-thesis, redistributing some categories of Angenot (1970) as residential

[c] Figures of CBS http://statline.cbs.nl/StatWeb/selection/default.aspx?DM=SLNL&PA=37105&VW=T with a different categorisation and some categories not specified.

[d] NNAO(1986) *Ontspannen scenario* (Den Haag) MESO The sources of the report are destroyed by fire in 2008.

1983	**hr/ inhabitant**	**m²/ inhabitant**	**hr/ m²**
infrastructure	387	91	4
government	61	1	61
offices	51	3	17
industry	298	67	4
shops	238	2	119
education	374	6	62
cultural	539	8	67
care	77	4	19
recreation	198	64	3
residential	6526	137	48
total, average	**8749**	**383**	**41**
(agriculture	11	1667	0.01)

Fig. 212 Intensity of use[d]

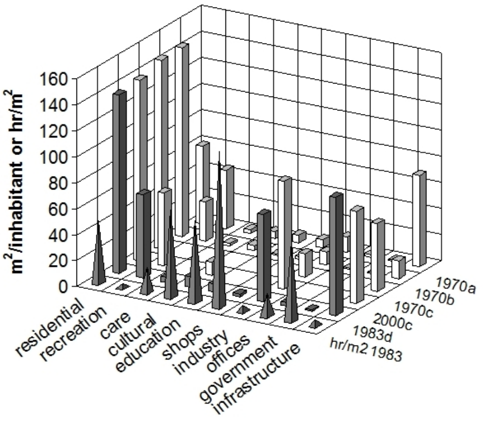
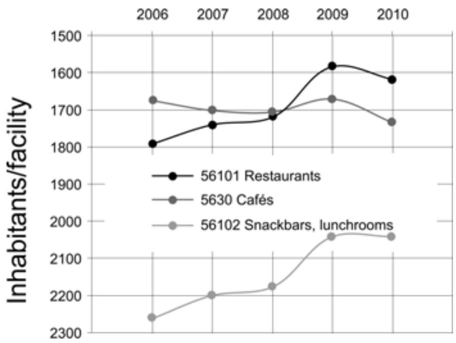


Fig. 213 Surface and intensity[abcd]

The Dutch paved public space counted ample 1100km^2 in 2010. If, on average, 16 million people are on the road half an hour per day, then every square meter is used less than 3 hr/year. If you suppose streets to be empty at night, then it still comes down to only one person in a 20m wide street of 100m length (2000m^2) at average per day. You do not expect such an emptiness, because you mainly visit busy streets at busy periods. This implies, that the other streets at other periods are even more empty than the average. The conclusion must be, that the locations where an adequate amount of visitors to support shops and other visitor-dependent facilities are limited and scarce.

The economic value of facilities

A low intensity of use does not always imply a low value. On the contrary, facilities such as recreation in *Fig. 212* (including parks and playing fields), may obtain their value by a low intensity. Shops, however, cannot pay back their investments without a high intensity of use. Internet shopping may reduce the intensity of use in specialised town shopping areas. Information and communication technology may reduce the use of offices and workplaces. Much work can be done at home through ICT.



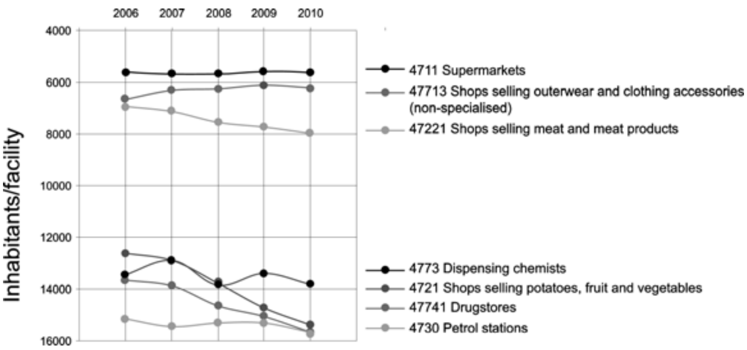


Fig. 214 R=300m increasing … *Fig. 215 … and R=1km decreasing support*[e]

The residential environment and the neighbourhood then may become more important. Some facilities are returning to the home, saving time and increasing choice, but this phenomenon may also stimulate people to go out to dinner in the neighbourhood.
The number of inhabitants required for the economic survival of a restaurant in the

[a] Angenot(1970)Collegediktaat stedelijke elementen(Delft)TH Bk
[b] Jong(1978)Milieudifferentiatie(Delft)TH PhD-thesis, redistributing some categories of Angenot (1970) as residential
[c] Figures of CBS http://statline.cbs.nl/StatWeb/selection/default.aspx?DM=SLNL&PA=37105&VW=T with a different categorisation and some categories not specified
[d] MESO(1986)Ontspannen scenario(Den Haag) NNAO The sources of the report are destroyed by fire in 2008
[e] http://www.cbs.nl

Netherlands recently decreased from 1800 into 1600 (neighbourhood level R=300m, see *Fig. 214*) in 4 years. Shops selling meat or vegetables and drug stores at the district level (R=1km) declined in the same period. They required thousands more of inhabitants to survive, probably due to competition with the supermarkets (see *Fig. 215*).
Bookshops and other specialised retail disappeared at the level of a town centre. They probably lost the competition with the internet. Specialised drugstores, greengrocer's shops and butchers may help district centres survive by attracting more potential visitors in town centres.

The ecological value of facilities

Money and payment cannot always determine the value of facilities and affordances in the long term. The carrying capacity of the Earth, our technology and economy may be imagined as tanks filled with liquids of decreasing specific gravity (see *Fig. 216*, comparable to *Fig. 45* on page 83). They will loose liquid (carrying capacity) if the upper tank becomes too heavy. The values of facilties are compared in a conditional sequence determining strategies of sustainability. A more fundamental and practical ecological comparison of natural and artificial structures may express their value in kilometres and years (see *Fig. 217*). The kilometres represent the distance into the next example (rarity), while the years express the time required to replace the structure (replaceability). The ecological value may be expressed by their product: rarity times replaceability. This method appeared to be convincing in order to evaluate urban plans ecologically in Almere[a]

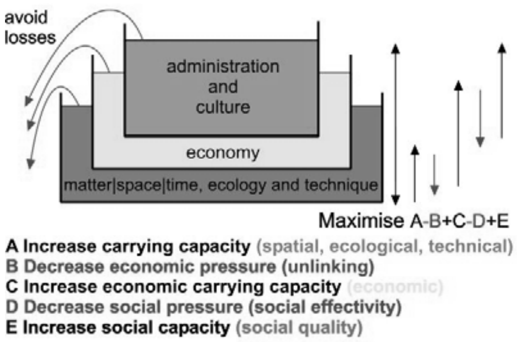


Fig. 216 Carrying capacity

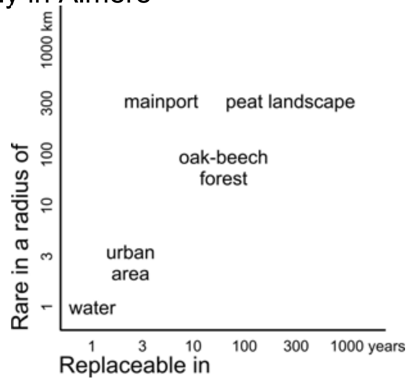


Fig. 217 Rarity and replaceability

The designer’s limited role in giving function

It is not the task of a designer to *determine* functions, but to make them *possible*. Paintings with a *determined* political, commercial or emotional function may become predictable kitsch. A piece of art should surprise, without losing sufficient possibilities of recognition. There should be more than one possible interpretation for it to remain surprising and recognisable for a long period of time. Spatial design creates conditions that give the users freedom of choice for a longer period than the first ownership. The means of spatial design select the *content*, *form* and *structure* of an environment. The *content* determines its possible differences and changes, including their zero-point of equality and continuity. *Form* determines the dispersion in space of their values, making separations and connections (structure) possible. *Structure* enables selection. Selection enables life and its economy, including human life. The history of living together has specialised society into spatial, ecological, technical, economic, cultural and managerial tasks. It is the inward functional diversification that is discussed in 6.3, from page 225 onwards. These tasks developed institutions at different levels of scale. Any spatial initiative should coordinate the intentions of many interested parties from this context.

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[a] Jong (2001) *Ecologische toetsing van drie visies op Almere Pampus* (Zoetermeer) MESO

Functions ⇓ facilities ⇓ supply ⇓ demand ⇓ needs ⇓ conditions

All accessible facilities together should be sufficient to live a satisfying life. The motivating physical, social and psychological needs, however, change. They cause changes in facilities that are supplied by the market, based on sufficient demand (e.g. those of *Fig. 214* and *Fig. 215*). A sufficient economic demand, however, still may not cover all individual human needs. Human needs become observable if *conditions* to live a satisfying life are not fulfilled. Some of them may be unnoticed by the *possibilities* of a spatial environment. Space and time are primary conditions to exist, but they are not sufficient to survive. Hunters and collectors survived in different ecosystems. Farmers survived in autarkic farms. Modern people survive in towns. These ecosystems, farms and towns, with their varying facilities, obviously contained all conditions to survive. But, were they sufficient to live a *satisfying* life? Conflicts and criminal behaviour are signs of dissatisfaction. The urban life may have gained satisfying conditions and lost other ones in spite of the supply by many facilities. If there would exist a checklist specifying all (partially silent) conditions for a satisfying human life, then the shortages of any residential environment could be distinguished by checking the list. The limited contribution of any facility could be counted. Their accessibility within any space-time budget could be determined. There are, however, different space-time budgets. Unemployed people may have enough time, but they may not have sufficient access to space in order to effectively utilise their time. Employed people may have enough access to space, but may not have sufficient time to utilise it. Even if you manage to balance these primary conditions of existence (space and time), then the stability of their balance may bother you. Even if you manage to safeguard that balance, then you may become bored or teased by a new dissatisfaction. Moderate dissatisfaction motivates, but too much negative conditions increases personal frustration. The checklist of conditions should not summarise everybody's actual outward functions, but rather, the *possibilities* of their fulfilment, and the *conditions* that make such functions *possible*. The sections below are an attempt to make such a checklist. It is necessarily an abstract exercise to be interpreted and elaborated differently in different cases. On the other hand, it should be concrete enough to be applicable. This section summarises the physical conditions that may be fulfilled by spatial design. The next sections will modify them in regards to the perspective of human needs. A further theoretical elaboration should be the subject of another publication.[a]

The condition of space

Without space, nothing can exist. Space is a crucial condition for any human function, but how much space is required in total to exist, to survive, to live a satisfactory life?
The surface of the Earth is an ample half a billion km^2. If you share it with 7 billion people, your part is at average $0.07km^2$, divided in approximately 5ha of sea, and 2ha of land. Your 0.2ha of agriculture is half luxury crops or cattle, and half crops that are crucial for survival, such as corn (see *Fig. 218*). The rest is nature, which is continuously declining by exploitation. When I was born, I 'had' twice as much space, and when I die these figures may be halved again. The green revolution amply doubled the production per ha, mainly through artificial manure, with phosphate as a crucial component. It is developed from a limited number of mines in Morocco and China. They will be exhausted in this century or the next. How many people may survive finally? What is their final spatial requirement? What is 'space' as an ecological condition? Is it the space required to exist, to survive or to live a satisfying life? Article 1 of UN Declaration of human rights of 1948 reads: 'All human beings are born free and equal in dignity and rights.' This immediately raises the question of freedom. 'Space' provides a freedom of choice, 'time' provides a freedom of action, but space and time are not equally distributed by birth, acquisition time and death.

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[a] Jong(1992) *Kleine methodologie voor ontwerpend onderzoek* (Meppel) Boom http://team.bk.tudelft.nl/Publications/1992/Jong(1992)Kleine%20methodologie%20voor%20ontwerpend%20onderzoek(Meppel)Boom.pdf

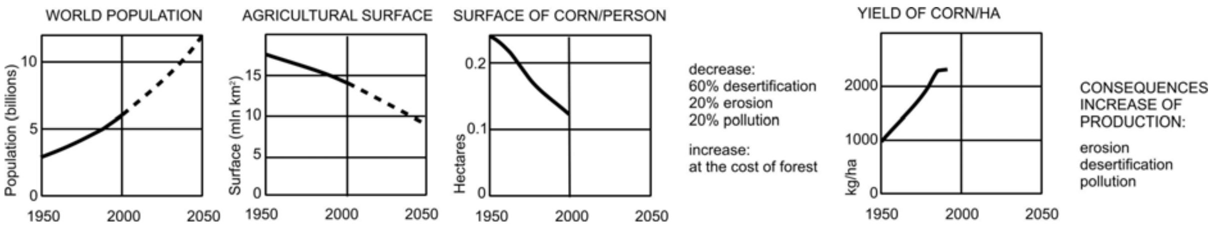

Fig. 218 Increasing population, decreasing agricultural surface, increasing productivity[a]

You may increase private property (e.g. land ownership) through personal effort, but is broadly accepted as inheritable, and any effort requires space and time. They are more or less inversely proportional. Less space (less freedom of choice) requires more effort, more time. In principle, public space safeguards the physical accessibility of facilities, which enables anybody to live a satisfying life. 'In principle', because there are other conditions that need to be fulfilled. It still does not solve the problem of an unequal distribution of time.

The condition of time

An interfunctional activity invests time to obtain a greater profit afterwards. Toolmaking, growing crops, learning to become a well-paid specialist, being employed, saving money, investing it, designing and planning, all postpone the reward, in order to increase it. Even money itself is a delay of reward. Money represents saved 'time' and 'space', freedom of action, and freedom of choice. You invest time now to obtain more later. Education, for example, is an interfunctional activity that promises a higher income the more you study. It places you in a dilemma, because spending time for education does not stop living costs, and you have to pay the teacher. You have to invest before you can harvest, but the yield is uncertain. You cannot decide whether a specialisation suits your talent before you have practiced it. The media feed your doubt by preferring to report exceptions, telling stories about millionaires without education. You have to balance unknown profits against the costs that increase with the time spent on studying. Most of the young people in the world need every minute for direct survival. They cannot invest anything. If they do not survive, then their time is over, nobody will hear anything about them anymore. Nobody will care. They are not the exceptions that are interesting enough for a newspaper. Time is unequally distributed, but even if you have time to invest, and space to choose your direction, then there are still many more conditions that need to be fulfilled.

The condition of content

The freedom to choose a direction (space), and to move (time), is a prerequisite for use. This freedom, however, is still useless in a space without content. You may be free to walk in any direction, but without water, food and many kinds of protection, you cannot survive. As soon as the interest of people goes beyond mere survival, the required content increases. Some of these facilities are mentioned in *Fig. 205*, but populations are different, and the requirements of future generations will be different from ours. Many resources are running out, which changes the kind of facilities we need. Approximately 1000 species become extinct every year. We do not know their function in the ecosystem we belong to. Only recently, our engineers attempted to imitate the biological performances and chemical processes they did not previously think to be possible (bio-mimicry), but nature still remains superior. For example, after the discovery of the Anamox bacteria[b], the nitrogen cycle appeared to be totally different from what we learned in high school. It is now used in industry to purify water, because it still performs cheaper than our imitations. We would not have been able to invent its process if it would have become extinct before we discovered it. Many of our medicines originate from the biological treasury.[c] We do not know what we lose.

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[a] Jong(1995) Doom scenario rough estimates
[b] http://en.wikipedia.org/wiki/Anammox
[c] Civian, Bernstein(2008) *Sustaining Life. How Human Health Depends upon Biodiversity*(Oxford) Oxford University Press

The natural answer to uncertainty and risk is diversity. The diversity of our human environment is limited compared to nature, and it causes an unprecedented mass-extinction. Some variables of *possible* diversity are summarised in Chapter 3, but it is still a poor list. From a viewpoint of risk reduction, any possibility to diversify the content of space should be utilised. At some locations in our cities, the number of wild plant species already exceeds 350/km^2 (more than in many nature reserves). Nature appears to discover and utilise a diversity we created unconsciously. Providing different locations with a different content provides 'identity' to any location. Even the police ask your name and address to determine who you are. It is the continuity of descent, and the difference of origin. Where you live is obviously part of who you are. If your home is exchangeable and anonymous, then you have to search for a unique identity through action, be it positive or negative.

The condition of form

Resources and facilities must be available within different spans of time: water, energy and protection every second, food, education, employment every day, other facilities every week, month or year. What you need every second should be everywhere, what you need every day should be available within a day, and so on. The available facilities are laid out at different distances. These distances determine the *form* of your environment. From the point where you are, the distances of the building materials of your house determine its form. Form is often primarily conceived as a visual property, but it is also a substantial condition for construction and use ('visual use' included). Form is the distribution of any content in space between total accumulation and total dispersion (see Chapter 4). Some content, such as air, must be totally dispersed to be useful, while other content, such as poisonous matter, should be concentrated and separated. It is easier to dissolve sugar in your coffee, than to get the dispersed sugar back in its originally concentrated form. This does not apply for sugar only. De-concentration is more probable and easier to achieve than concentration. Clearing up your room, is *concentrating* its different contents into different locations. Dispersing CO_2 in the air is easy, but to concentrate it is difficult. Against the main flow dictated by the laws of thermodynamics, plants collect CO_2 and concentrate it as hydrocarbons C_xH_y ,using the power of sunlight. It took millions of years to store hydrocarbon as coal, petrol or gas in the sub-soil, until humans dug it up and dispersed it into the air. Any economic activity, however, is a process containing phases of collecting and distributing some content (see *Fig. 179*). Any facility or household collects and distributes. Any artefact is a product of concentrated content with a distribution in space, a form. To use them, however, there is still a condition that needs to be fulfilled, the condition of structure. Structure stabilises a form, which keeps it useful.

The condition of structure

Any outward function requires access to facilities and protection against threats. It requires a structure operating selectively by connections and separations. Modern society and its habitat provide structure. It seems normal. You become aware of it in the case of war. Separations that protect you then may be destroyed, and connections may fail. You cannot expect them to be operational anymore. People with an experience of the state of war may appreciate structure more than those who do not. Chapter 5 has demonstrated polarities at any level of scale between 'open' and 'closed' environments. Going out is an example of leaving a closed environment, which selectively connects you with the required facilities, but it exposes you to risks from rain to robbery. At any level of scale, however, structure plays a role of stabilising useful distributions in space through connections and separations. No specialised facility or household may function without a stabilised network of connections with specialised and separated facilities. Specialisation requires organisation: separating different tasks at different locations, connecting them selectively, and avoiding disturbance.

6.5 Failing conditions as a challenge for design

More than physical requirements

Space, time, content, form and structure are physical conditions for human functioning. They successively enable freedom of choice and action, the availability of resources in time, their effective distribution in space, and they are stable enough to use them. Content, form and structure may be the direct object of design, but the physical conditions are taken for granted by the users as self-evident, as soon as they are realised. They do not directly answer the biological and conceptual needs that motivate their daily actions. They only make them possible. To include these human needs and to relate them more directly to the A-biotic ones you may provide as a designer, you can add Biological and Conceptual conditions to the checklist (ABC-model, see *Fig. 45* on page 83). This will put them in the perspective of human intentions (the subject of the next Chapter).

Human needs as lacking conditions

Maslow's theory of motivation[a] (see *Fig. 44* on page 83) does not even mention the a-biotic conditions separately. It takes them for granted in 'physiological needs'. Once they are fulfilled, needs for safety, affection, esteem and self-actualisation may follow in a sequence of 'prepotency'. This sequence is similar to the sequence in *Fig. 45* of a-biotic conditions (A) shaping the possibility of life (B), and enabling conceptual performance(C), but it hides A and B. It is also similar to the sequence of space-time, ecological, technical, economic, cultural and managerial conditions (see *Fig. 46* on page 83, utilised in section 6.3 from page 225 onward), but Maslow's sequence is more specific at an individual level.
Any of these distinctions show a 'conditional sequence', a sequence by which the next condition cannot be achieved before the preceding condition is fulfilled (at least to a certain extent). If one of the previous conditions is missing, the next cannot emerge. Conditions do not *cause* anything, they only make things *possible*. The other way around, the next condition *supposes* ($\Downarrow$) the previous one. C $\Downarrow$ B $\Downarrow$ A ; self-actualisation $\Downarrow$ esteem $\Downarrow$ affection and so on; management $\Downarrow$ culture $\Downarrow$ economy and so on.
In the same way, the chapters of this thesis suppose each other: function $\Downarrow$ structure $\Downarrow$ form $\Downarrow$ content (see *Fig. 4* on page 18).

Biotic and conceptual conditions

According to Maslow, the last human need – 'self-actualisation' – supposes esteem. Maslow apparently cannot imagine 'self-actualisation' without 'esteem': the recognition of your achievements by others, and their respect or even admiration (prestige). It then supposes that you are dependent on their judgement to reach a state of 'self-actualisation'. Such a dependency I would rather call 'self-denial'. Prestige is a well-known biological function for survival by hierarchy in groups of wolves or apes, in order to command coherent behaviour in case of danger, through obedience. I accept the authority of authorities because they take care of the structure I need to function. To obtain esteem in a group is a very common human inclination, but it is not typically human. It belongs to the biological layer between a-biotic and conceptual conditions for a satisfying life. If 'esteem' becomes part of the competition between individuals, then the winner would obtain the most satisfying life, and a majority of losers would not. Stimulating ambition in this majority is using the most common biological inclination of competition to stimulate their effort in maintaining the existing structure. What, then, are the *conceptual* conditions, not being a part of the conditions known from biology, but so typically human?

[a] Maslow(1943) *A theory of human motivation* (Psychological Review 50)50 p 370 - 396

Conceptual conditions

I cannot imagine a satisfying human life without a satisfying self-image. A satisfying self-image is the reflexive concept of a unique individual, free to choose and to act in sufficient space and time. A subsequent human life is satisfying, if this freedom can be actualised by some influence in the environment that mirrors the individual, and confirms his/her self-concept. The uniqueness is part of a broader concept of 'identity' (*difference* from the rest and continuity in itself). Where Erikson[a] emphasised its biological roots, I would like to distinguish its conceptual upper layer first. The human identity develops by alternating inward and outward functions known as identification and projection. Birth separates mother and child by the parturition (*partus*). If you would have had any concept of that event at all, it must have been a change from being part of an all-embracing body without much sensory diversification or orientation, into an environment full of differences between cold and warm, light and dark, satisfying and unsatisfying. The continuous satisfaction, then, should have caused a state of unconscousness comparable to sleep. Only a dissatisfaction after birth may have motivated you into a consciousness and imagination separated from the unsatisfactory reality and into expression and action. It must have taken some time before you might have recognised something in the 'tableau mouvant', as Piaget[b] called the chaos of impressions you have been exposed to after birth. It is very probable that the first object you have recognised, has been your mother as a unique source of satisfaction between all appearing and disappearing objects. This uncertain world should have raised a feeling of unsafety. Her warm embrace and feeding reunited you, reminding you of your prenatal stage. Satisfaction is the biological root of affection. Its conceptual component is primarily the concept, or non-concept, of *unity*. The *awareness* of unity cannot emerge without an experience of separation. A disturbed unity, however, can be restored conceptually by identification and projection. Identifying yourself with your mother, your father or the other objects, replaces the kind of unity you miss (in-dividuality means un-dividedness). Imitating them incorporates their presence in absence. Projecting your desires and imagination upon them may disappoint, if they still do not supply what you want. The failing unity increases the awareness of separation and difference from the rest, and forms the very beginning of identity. The function of identification and projection is recognisable in the history of art as impressionism and expressionism. If projection disappoints, then you may express your desires and imagination in words and drawings. Mastering language through imitation is another way to restore a unity conceptually. The conceptual basis of this process, however, is the availability of surprising impressions with some repetition enabling recognition. Beauty is the balance between surprise and recognition, in order to avoid passing the limits into chaos and boredom (see *Fig. 6* on page 21). Boredom is killing. Babies in homogeneous environments without any difference or change die[c]. Experiments on sensory deprivation of adults lead to hallucinations[d]. At the other hand, chaos without any possibility of recognition cannot produce a conceptual ability to separate and incorporate an image from your environment. These kinds of dissatisfaction urge you to outward involvement and influence in order to obtain your own order of recognition and surprise. This personal order can be expressed in an extended territory for projection and identification. *Fig. 219* summarises the inference above in 5 key words, representing conceptual requirements in a conditional sequence.

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[a] Erikson(1968) *Identity youth and crisis* (New York) Norton

[b] Piaget;Inhelder(1947) *La representation de l'espace chez l'enfant* (Paris) Presses universitaire de France

[c] Spitz(1945) Hospitalism: An inquiry into the genesis of psychiatric conditions in early childhood **IN** Psychoanalytic Study of the Child. Vol 1 (New York) International Universities Press p53-74

[d] Vernon(1963) Inside the black room, studies of sensory deprivation (London) Penguin

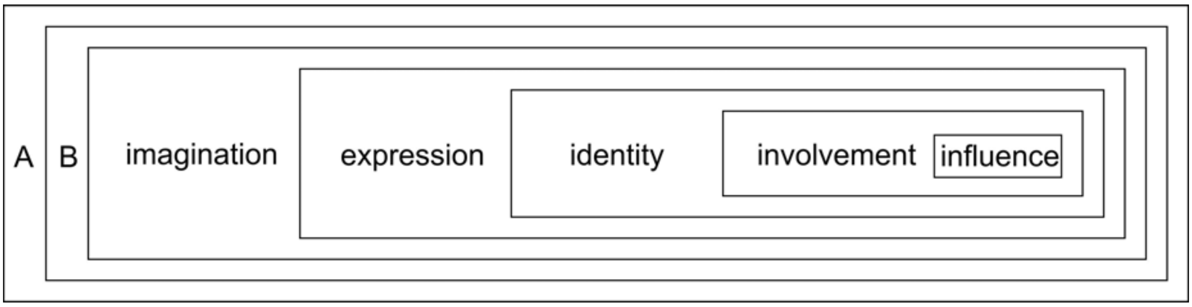

Fig. 219 Conceptual conditions

You can choose other key words, but I avoided the emotional load of terms such as surprise, recognition, affection, esteem and self-realisation stemming from the biological layer (B) to be elaborated in the next paragraph, on its turn supposing the a-biotic layer (A). You can add many more conditions in between, but I restricted myself to the 5 derived from Maslow's categorisation, cleared from its biotic components.

The concept of 'concept'

One of the remaining questions is the concept of ´concept´ itself. If a conceptual ability is supposed to distinguish humans from the other animals and conceptual conditions (C) from biological ones (B), what, then, is its definition? In this thesis it is defined as ´the image of a sequence of actions, taken together with their conditions´[a] A tool making ape may also foresee a sequence of actions, but it is a small range compared to the many interfunctional actions a human can foresee postponing the final reward. The size of the range may matter, but this ability covers any other criterion. The often presented criterion of tool making or language supposes imagining a sequence of operations or words. Ethics supposes an ability to foresee the consequences of what you do. Task division supposes you can imagine a sequence of different actions, and so on. 'Con-cept' thus is precisely what it means in Latin: 'taken together'.

Biotic conditions

Fig. 220 summarises in advance what I will explain below. A-biotic conditions (A) are supposed in the conditions of life, finally enabling the conceptual conditions (C).
I chose these 5 key words from the many imaginable biotic conditions making life possible, because they represent the many others and they show a relation with *Fig. 219*.

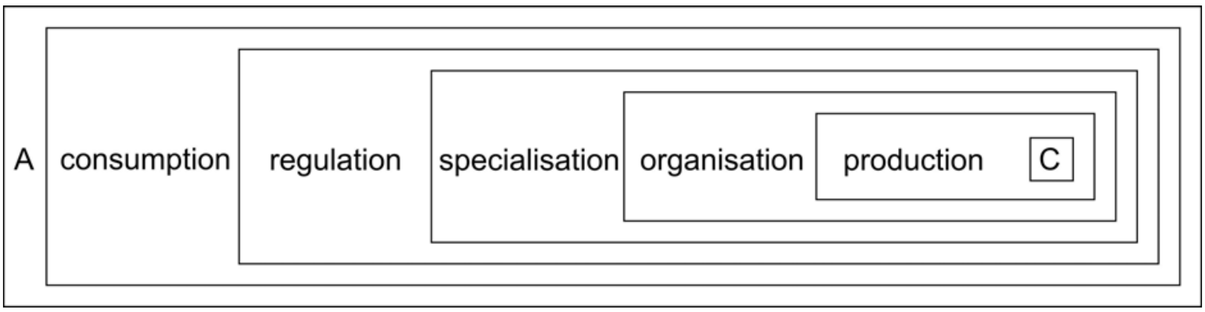

Fig. 220 Biotic conditions

Reproduction is often taken as the primary criterion of life, but then a mule would not 'live'. It is an animal not able to reproduce itself, but it is still a product of sexual reproduction. It is not *possible* without biotic production as a condition. Moreover, it is an animal with organs organised in an organism, the under-laying criterion of life. The term 'organisation' is mainly

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[a] Harrison;Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press, stresses the 'foreseen sequence of actions', but I introduced 'image' of which the origin is usually referring to 'imitation'. However, I would rather refer to 'in-machina', (internal tool).

used in a human context, but it is essentially biotic. On its turn it supposes the *specialisation* of organs. In ecology, specialised species are not 'organised' as organs in an organism. You therefore can imagine specialisation without organisation, but you cannot imagine organisation without specialisation. This inference is the 'conditional test' I use to determine any conditional sequence. It is the way I tested many pairs of categories. Specialisation is the core of functional diversification, and regulation is its under-laying condition. Different plant species are specialised to survive in different climates and on different soils. In ecology, rare plant species are particularly found on poor grounds. They must regulate their consumption very carefully to survive. In a hot and dry climate, they save water. On acid grounds, some of them compensate for their lack of nitrogen by catching insects. In any species, however, numerous regulating mechanisms compose complex chemical compounds travelling through changing environments, thereby decomposing other compositions bit by bit successively, delivering the required matter and energy at different locations. The required regulations are stored in genes and distributed by messengers, much like they are stored in procedures and distributed by people in a human society. Regulation supposes consumption of matter, minerals, energy and information that is selected from an environment. Selection, however, is not an exclusively biotic phenomenon. It is an a-biotic condition for life, which makes selective consumption possible in different environments. This makes environmental diversity into a crucial a-biotic condition. The biotic conditions of *Fig. 220* are a checklist for economy or sustainability. Where does our exploitation of the Earth fail? Is the consumption, its regulation, task division, organisation or a kind of (re)production disturbed? Designers search for new, improbable physical possibilities to utilise space, thereby increasing the diversity of its a-biotic conditions: content, form and structure.
Chapter 3 elaborated on the *content* of space, by summarising legend units and values that may vary in space and time, and then by categorising them as variables.
Chapter 4 studied the possibilities of their distribution in space and their *form*, which is limited by the extremes of total accumulation and total dispersion.
Chapter 5 studied the possibilities to stabilise their form through separations and connections, or its *structure*.
This Chapter searches the limits of use and the boundary conditions of possible *functions*.

A-biotic conditions

The possibilities of life (including human life) are limited by physical conditions, such as available space, time and matter.

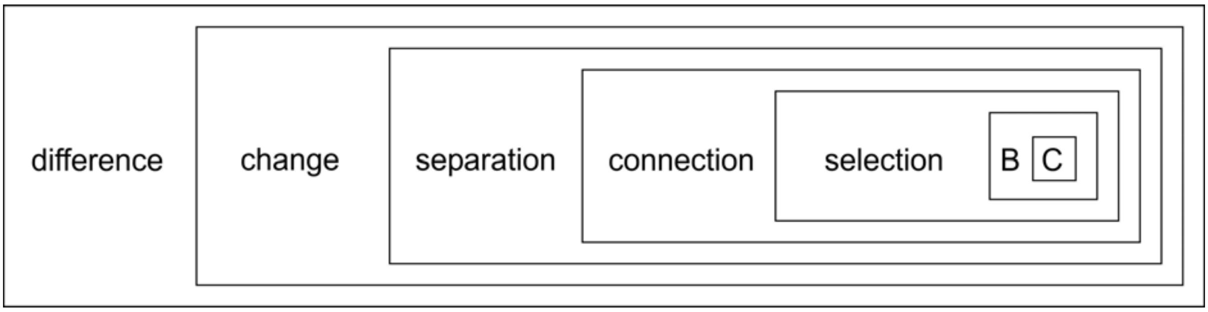

Fig. 221 A-biotic conditions

Section 6.4 studied space, time, content, form and structure as the conditions of use. This categorisation may be useful for design, but these categories are not directly connected to our experiences, needs, choices and actions. For example, the concepts of space and time are constructions of the mind that you cannot immediately explain to a child. You have to refer to their more direct appearance as *difference* and *change*, in order to develop such abstract concepts. The Newtonian concepts of space, time and mass are intended to compare, and to measure *after* such experiences. Even our concept of form is not as obvious as it looks. It supposes different distances between parts distributed in space. Distances, however, are not obvious either, without any motoric experience of movement, or change of position.[a] Distance is primarily experienced as *separation*. For a baby, there must be only two distances: what you can grasp and what you cannot grasp. Movement adds an awareness of more distances, by referring to the effort it takes to reach what you see. But, the primary experience is separation. However, separation includes more than distance. There are separations hampering movement itself, such as solid objects, fences and walls. They increase the initial separation by distance, forcing you to make detours. To translate the abstract design concepts of space, time, content, form and structure into categories of direct human experience and needs, I chose other boundaries to categorise the same conditions in *Fig. 221*. Space and time cannot be experienced and understood without differences and changes of some content. Form, which can be considered as dispersion in space, cannot be experienced and understood without an experience of distance, which is a kind of separation. Connections such as arteries, roads, tunnels, doors and windows overcome distances, or break through material obstacles, such as solid objects, fences and walls: separations. They suppose some kind of separation that must be overcome, or they suppose separations perpendicular to the direction of connection, in order to steer movements in the right direction (see *Fig. 8* on page 29). Selection thus supposes 'connecting separately'. Selection is crucial for any biotic (B) phenomenon, including human functioning (C).

Some repetition in the ABC sequence

Fig. 222 summarises successive conditions as they are delineated above.
Difference is the first condition, because any next condition supposes some difference. You cannot imagine any next a-biotic, biotic or conceptual condition without *some* fulfilment of this primary condition. It does not suppose an extreme amount of difference, but an optimum in between too much and too little difference (see *Fig. 6* on page 16 or *Fig. 64* on page 102).

	1	**2**	**3**	**4**	**5**
A A-biotic	difference	change	separation	connection	selection
B Biotic	consumption	regulation	specialisation	organisation	production
C Conceptual	imagination	expression	identity	involvement	influence

Fig. 222 A checklist of conditions

The first condition of a next row directly supposes the last condition of the preceding row. A conceptual imagination tacitly supposes a biotic organism producing it. Biotic consumption supposes a-biotic selection. Conditions cannot be expressed in words, without this context of sequence. The conditional sequence may shift the usual meaning of the chosen key words into the direction of what they actually should cover as a condition. 'Consumption' may have a meaning that is slightly different from usual, if it is conditionally located here between selection and regulation. Consumption, in its economic sense of 'use', is necessary to make any regulation of this use possible. How could you regulate anything if nothing comes in? If you select something from your plate and eat it, this consumption is a condition for regulation. If you take regulation as a change through feedback, then there is an initial 'feeding' supposed in the concept of regulation. You may be satisfied by eating for a while, and even talk a little instead of eating. To cover 'feeding', I took 'consumption' as a better key word than 'use', but I still doubt if I chose the right key words.

[a] Held;Hein(1963) *Movement-produced stimulation in the development of visually guided behavior* (Journal of Comparative and Physiological Psychology) 56 5 p 872-876

Conditional tests

The boundaries of conditions can be chosen in many ways, and many more conditions could have been distinguished. But, this categorisation provided rows with a comparable sequence, producing columns as a second possibility in *Fig. 222*, in order to determine the meaning of the chosen key words. In a former publication[a], I supposed organisation as a condition for specialisation, and in the conceptual layer, I consequently supposed ‘affection’ as a condition for ‘autonomy’ according to Maslow, but I am now convinced that it is the other way around. I cannot imagine affection without autonomy, but I can imagine autonomy without affection. A conditional test forces you to sharpen your definitions. What did I include in the term ‘affection’, imagining it without autonomy, and what do I exclude now, *not* being able to imagine it without autonomy? It is the kind of ‘forced affection’, known from cases of hostage. After some days, the hostage begins to show ‘affection’ for the kidnapper. This kind of affection surprises psychologists, but I would not call it affection anymore. It is the consequence of losing autonomy, falling back in a non-conceptual biotic state of mere survival, through surrender and subjection as an unborn baby without identity, as being part of another organism. The organisation is changed by the most simple specialisations of ‘slave’ and ‘master’. Your biotic reaction of mindless obedience has no name, and you call it ‘affection’. It is the same affection without involvement that also appears in populations under absolute and merciless dictatorship

Vertical equivalence

If there is a comparable sequence in the rows, then there also should be some relation between the words in a column of *Fig. 222*, but what kind of relation is it, more than the already existing conditional relation? Is it a relation of equivalence? Could you imagine ‘consumption’ as a biotic equivalent of an a-biotic ‘difference’? Is ‘imagination’ a conceptual equivalent of biotic ‘consumption’? Both questions raised by column 1 may be answered, if you interpret ‘consumption’ as ‘impression’ in its literal sense, as imprint, a thin boundary between the consumer and the consumed, the primary difference. Imagination, then, may be a product of the mind that is equivalent to this impression.

Expressions

Subsequently, expressing an imagination may be interpreted as a transformation, equivalent to change and regulation in column 2 and regulating the consumed. Words change the diversity of your imagination into regulated standard expressions. They equalise your impressions, faded by selective memory. Perhaps any change reduces differences, as Van Leeuwen observed in ecology (see *Fig. 10* on page 36). The equivalent of change in the conceptual layer, however, may also produce something new. Expressing your ideas in a drawing may change them, producing new imaginations through the feedback of what you expressed. This interaction with your expressions is a well-known primary process in design. One of your designs is your identity, by the way.

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[a] Jong(1992)***Kleine*** *methodologie voor ontwerpend onderzoek*(Meppel)Boom

Checking possible functions

This checklist cannot be used to check the presence of usual facilities. It may suggest unusual facilities, if you interpret these abstract key words with some additional imagination. It can be used to investigate which absent conditions may identify the human needs that are unfulfilled. Some of these recognised needs raise a sufficient demand to evoke a supply. (see page 233). Others do not. They even may be not be recognised. They may insidiously spread as hidden dissatisfactions that are replaced by using insufficient facilities. The less vitamins your food contains, the more you need. The less stimuli your environment provides, the more false alternatives you will try. Our body, and its senses, have been developed in the rain forest during some 3 000 000 years. It supplied an inconceivable diversity of visual impressions, sounds, smells and challenges. It provided sufficient difference, change, separation, connection, selection, consumption, regulation, specialisation, organisation, production, imagination, expression, identity, involvement, influence. How does the urban jungle perform, compared to this prototypical environment? Our genes developed in this environment, and they did not change much in the past 10 000 years. Our environment did. Substantial specialisation created homogeneous environments that required repeating interfunctional actions between 8 and 17 o'clock. For many people (probably not the rare readers of this thesis), these hours are both boring and stressful. These experiences must be compensated for after work through a sudden change from public functioning into private seclusion in the home. There, looking for connections with family, television, internet, telephone or outdoors, a kind of indecisiveness may emerge. These possibilities do not allow anything *in between*, where you can hesitate. Aldo Van Eyck criticised modern architecture for its lack of 'in between realms':

> '*Bird's nest and bird's flight and bird.*
> Take off your shoes and walk along the beach through the ocean's last thin sheet of water gliding landwards and seawards. You feel reconciled in a way you would not feel if there were a forced dialogue between you and either one or the other of these great phenomena. For here, in between land and ocean – in this in between realm, something happens to you that is quite different from the seaman's alternating nostalgia. No landward yearning from the sea, no seaward yearning from the land. No yearning for the alternative – no escape from one into the other. Now there is nothing wrong with the seaman, as long as we realize that he is always wanting to go home both ways.'[a]

Why could you not *sit* in a door, enjoying both the inside and the outside of your home.
Why not postpone your decision to connect or to separate?
The simple experience of a walk in a diverse environment is a continuous exercise of separation and connection, leaving behind what you passed, and exploring what is in front of you. Such experiences of give and take exercise the art of selection.

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[a] Eyck;Parin;Morgenthaler(1968) *Ecology in Design / Kaleidoscope of the mind / Miracle of Moderation / Image of Ourselves* (Via 1) p 129

7 Diversifying intention

7.1 Between needs and possibilities

Pushing needs and pulling possibilities

Intentions are human concepts that balance needs and possibilities (section 7.1).
Their attracting perspective on possibilities is limited in time and space (section 7.2). Their potential impact on different physical and social layers (section 7.3) depends on different expectations about the future context (section 7.4). A diversity of intentions may cause conflicts, but it also stimulates innovation, it diversifies the environment, and consequently, it provides freedom of intention for future generations. Spatial planning and design balance the diversity of intentions that require space. They connect a field of spatial problems (probable, but not desirable futures) with a field of aims (desirable, but not probable futures). This requires to make an inventory of desirable and probable futures as sets, in order to determine both subsets (see *Fig. 2* on page 17). They subsequently balance the field of aims against the possibilities in order to determine their possible function (section 7.5).

Outward intentions driven by needs

Failing conditions (see *Fig. 222* on page 242) raise vague needs, direct desires and more balanced intentions. Fluctuating desires may become a more durable intention if you have *thought* about them. Intentions thus are conceptualised desires, ready to be exchanged with other people. You may elaborate on them through plans, initiatives and projects. Realising a project, however, requires consensus; deviations cannot be tolerated anymore. The phase of intentions is the most innovative phase, if a diversity of intentions is tolerated. Production requires *equal* intentions, but innovation requires *different* intentions. Intentions are still receptive to other people's intentions. Your intention may change through exchange with different intentions. By discussing them, other vague needs and former desires may receive priority. You may become aware of possibilities that you did not realise before. These possibilities, however, also may evoke desires and intentions that are not really answering your needs. Existing supplies seduce, causing you to neglect the more urgent needs that you may not even be aware of. Some dissatisfaction may remain.

Inward intentions driven by possibilities

Commercial initiatives primarily realise an average of other people's intentions, by balancing them against the possibilities of economic production. They fulfil a limited set of supposed needs in a specialised market, or they *create* a demand through marketing. The primary intention of the initiator is to earn money by postponing and enabling immediate intentions of a private person at a lower level of scale. Initiatives changing the environment, however, have to take into account more different needs, desires and intentions. They have to be diversified in regards to their time span, levels, layers, and perspectives, in order to make combinations that provide an added value. Their diversity is an opportunity for innovation and unusual combinations, if you manage to balance its field of problems against its field of aims and means. Design searches for the possibilities of different content, form, structure and function. The longer the time span, the more changing intentions have to be taken into account. Diversity of intentions require and enable spatial diversity and freedom of choice for future generations.

Targets and means

Discussing your intentions usually raises the question 'What is your problem?'. The supposition behind this question is, that from this problem you can formulate targets, and from these targets you can make an inventory of means required to reach these targets. It is appreciated if you name one problem and one target as the most productive strategy. It is the strategy of *production*, but it hampers *innovation*. Innovation balances *fields* of problems, aims and means. Production originates in probability thinking, suppositions about probable futures, as far as they are not desirable. Commercial estimation of needs is restricted to probable desires as they appear in queries. The average sells best. It overlooks possibilities beyond what is probable. Designing is possibility thinking. It includes these probabilities, but its core aim is to find *improbable* possibilities, *improbable* means. A designer who is limited by probability would produce predictions and more of the same. A combination of traditional solutions looks new, but it is eclecticism. Solving a well-known problem causes new problems in the environment of its solution. It is a profitable strategy, because as a successful problem solver, you immediately will be asked to solve the next problem, even if you have caused it yourself. Looking from some distance, by taking a larger scale into account, you are a problem producer. Any single problem is part of a *field* of current and future problems with mutual relations. But, a designer searching for possibilities *beyond* the probable futures, desires and aims, raises uncertainties. You may fail if you are not predictable. If you only want to earn money, be predictable.

Means directed study

Problems formulated in a set of currently probable, but not desirable futures produce probable aims and traditional means. Our current problems, however, are not traditional. They stem not from our daily experience, but from another time span, level of scale, physical or social layer and perspective on the future. The daily experience of a designer is different form the daily experience of the future user. Exploring possibilities within your own perspective is not enough. The design thus would not serve other perspectives. A designer has to be able to imagine different probabilities and desirabilities in different possible future contexts. You cannot *know* them, but as a designer you have to be *aware* of them and able to *imagine* more possibilities than solutions for the current problems. A design requires many detailed decisions that are not related to social problems and aims. A designer is used to thinking about many alternatives of content, form and structure for the same function, serving the same needs, desires, intentions and aims. This work is means-directed, instead of aim-directed. Aims themselves have to be designed or chosen. At a larger time span, targets *are* means, they are means for an efficient production.

Ways to study possibilities

There are at least four kinds of design study (see *Fig. 50* on page 93).[a] If the object and its context are known, then you study existing designs (´design *research*´). If the object is known, but it is appearing in different contexts, then you study types (´typological *research*´). Both kinds of study are *re-search*. If the context (with its problems, aims and eventually even a programme of requirements or brief) is known, but the object still does not exist, then its study is what designers usually do ('design *study*'). But, what if both object and context are unknown and consequently variable and indeterminate? From an empirical point of view, a study with a variable object and a variable context is absurd. It cannot be productive. Without context, it cannot solve any problem, without object it cannot serve any objective. Still, the many useless experiments with electricity in the 18th century, which were conducted without even knowing what electricity was, were extremely productive in a longer time span. So, there also may be crucial possibility studies to be performed by design beyond the current problems and aims ('*study* by design'), but the time span to become productive may be long, and perhaps it will never serve any other aim than satisfying curiosity.

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[a] Jong;Voordt(2002)*Ways to study urban, architectural and technical design*(Delft)DUP Science

7.2 Time span and level of scale

Time span of intentions

The capacity to imagine a sequence of many subsequent actions (of which only the first is directly executable, while only the last rewards) distinguishes humans from animals.[a] This human capacity, however, is utilised differently by different people. A 'consumers' lifestyle requires direct reward, e.g. by living in the centre of the city with its concentration of facilities; 'familists' take time to raise children e.g. by living in suburbs, before they become consumers, and 'careerists' accept that you have to invest many years before you arrive where you want to be.[b] But, everyone may have intentions for the coming hour, tomorrow, the next weekend or for the next summer holiday. These personal outward intentions are relevant for design, but apart from these intentions, there are inward and outward intentions that are represented by institutions, companies and their employees. A national government has many inward intentions relevant for spatial design. Its outward intentions, represented by a ministry of foreign affairs and its diplomatic service, may be less relevant. A company, however, has outward intentions, based on its suppliers and consumers in the market, and inward intentions, such as its production and employees, both relevant for design. Their time span is diverse. Buildings are intended to be used for 10 to 100 years. Companies intend to survive as long as possible, but they mainly do not make plans for periods longer than a year, except for their capital goods, such as buildings. Government institutions may cover a longer time span through its laws, and urban and regional plans.

The relevance of time span

The relevance of time span for spatial design and environmental diversity may be clarified best by an extreme example. The Turkish municipality of Adapazarı (340 000 inhabitants in 2000) was hit by an earthquake of a 7.8 magnitude on the Richter scale, causing 17 000 casualties in 1999. The majority of its population lived in a plain surrounded by mountains. A serious earthquake causes liquifaction of its soil, and consequently the collapse of buildings. The population has since increased rapidly through natural growth and overflow from Istanbul. This increase has been wisely located in a new town on safer soil (see *Fig. 223*). In 2005, I made two scenarios for Adapazarı 2030. In the worst case, the population would increase to 2 million people, who would build new buildings in the plain (see *Fig. 224*). If there would be a similar earthquake in 2030, then the number of casualties could be as high as 120 000 people. In the best case (see *Fig. 225*), the municipality would manage to prevent additional construction in the plain. The municipality would locate more new towns at safe places in a ring around the plain connected by fast public transportation for 2.4 million inhabitants. It would relocate 200 000 inhabitants into these safe places, and keep the old Adapazarı centre with 100 000 inhabitants in reinforced buildings. People spend less time in recreational and industrial areas in more safe, low rise buildings. The municipality would, thus, transform the emptied districts of the old city into industrial and recreational areas. Proposed projects are evaluated based on this scenario. But the question is, whether this can be realised in 30 years. The recurrence time of similar earthquakes in this area was calculated at 30 years. Perhaps some places in the plain are safer to be built-up than others, depending on the thickness of the liquifying clay layer, and consequently the application of safe foundations. This would allow an intermediate scenario. This would, however, require more research, and research takes precious time.

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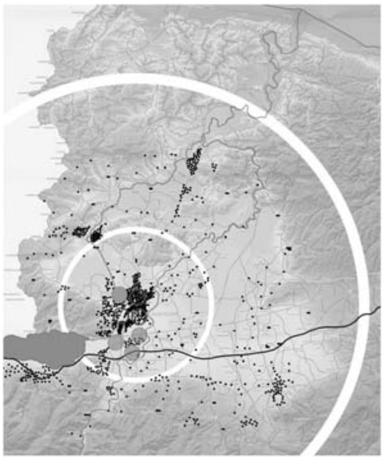
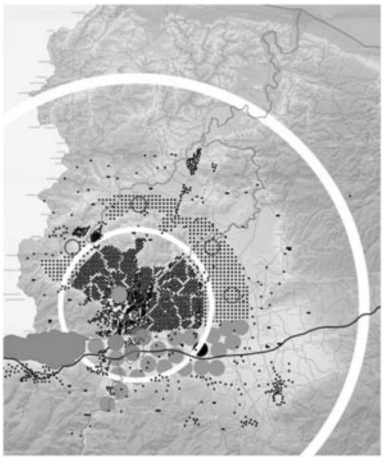
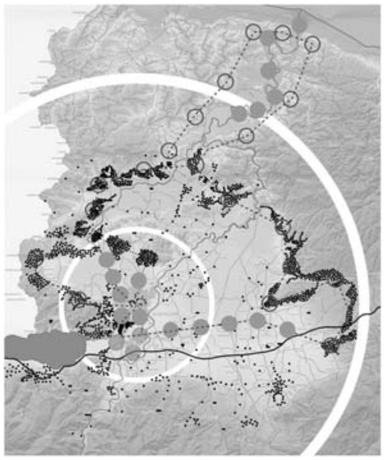
[a] Harrison;Weiner;Tanner;Barnicot(1964) *Human Biology* (Oxford) The Clarendon Press

[b] These life styles are distinguished as 'role emphasis' by Michelson(1970) Man and his urban environment(Reading)Addison Wesley.







R={30,10km} r=1km(100 000inhabitants or jobs) r=100m(1000inhabitants)

Fig. 223 Adapazarı 2000 *Fig. 224 Adapazarı worst case* *Fig. 225 Adapazarı 2030*

Extreme scenarios to calculate risks

Scenarios are possible futures, not plans. They make you aware of what could happen, and which chain of effects this could have. Then, you can decide what you should *know* in order to make plans, which is useful to reduce ecological, technical, economic, cultural and political risks in different futures. Applied knowledge reduces risks (chances x effects). Risks (including loss of human life and happiness) and knowledge both have their costs. To increase your knowledge takes time, and the passing of time *increases* risk, but increasing knowledge may *reduce* risks. When do you have to stop collecting knowledge and start making plans, in order to reduce the risks? We should start making plans as soon as the costs of increasing knowledge are higher than the costs of decreasing risks (see *Fig. 226*).

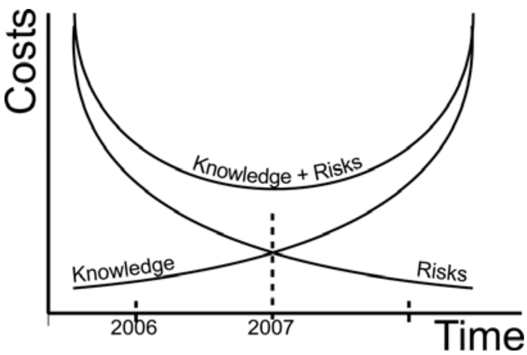


Fig. 226 The costs of increasing knowledge and reducing risks

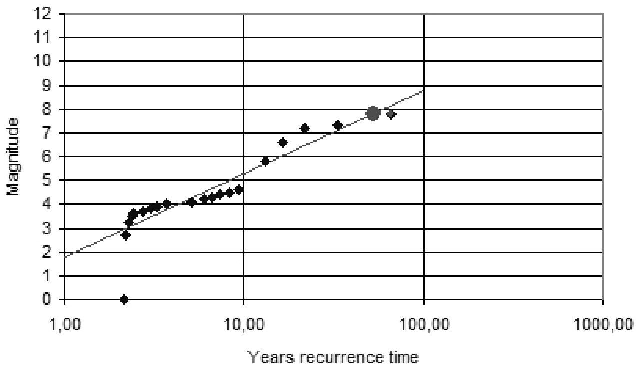


Fig. 227 Ranking the earthquakes 100km around Adapazarı in the past 50 years

For example, you decide to study the soil of the plain in the region of Adapazarı. For which points in a radius of 10km (see *Fig. 224*) would you collect such knowledge? If you drill 1km deep holes every hectare, then you have to drill 31 416 holes. That will cost precious time. You can look for more rough and advanced means of inquiry to reduce the time you need, but how reliable are they then? What is the probability that you make a mistake and cause casualties? The calculation of the recurrence time of similar earthquakes in the region (see *Fig. 227*) indicated that an earthquake of magnitude 7 may occur every 30 years, but an earthquake of magnitude 7.8 (as occurred in 1999) may occur every 60 years. If this is the difference between the buildings collapsing or not, then you may have more time.

A spatial imagination of time

The example of Adapazarı shows the importance of time spans. A different time span may change your intention. But, it also shows how changes and possible futures are expressed as *differences* with between images such as *Fig. 223* and *Fig. 224* or *Fig. 223* and *Fig. 225*. You can imagine them separately, but an awareness of change requires their difference. You can imagine space without time, but you cannot imagine time without a spatial frame (e.g. the municipality), and a grain (e.g. its inhabitants) where it works out. If your intentions are time dependent, then they are also space dependent. The intentions for Adapazarı between the worst and the best case scenario tacitly supposed alternatives at a regional scale, with serious effects occurring at a personal scale, which may determine if you live or die, depending on where you are. But, any intention may imply impacts at different levels of scale. If you want to build a sustainable house, then your intention may imply an impact on your family, your neighbours and a world-wide contribution in reducing CO_2-production. If you initiate a larger project, then you may hit still other intentions at different levels of scale. Some of them may support your initiative, others will not. How can you take them into account?

Space and time

During the past ten years, I chaired approximately 400 PhD ceremonies at the University of Technology in Delft (TUDelft). In 2004 and 2005, I asked 60 randomly distributed PhD candidates to draw the area in space and time covered by their thesis. *Fig. 228* shows what they told me. The area between meters and micrometers, and between seconds and days was apparently studied most. I seldom chaired the ceremonies of my own Faculty of Architecture, but the concentration of grey between 1m and 100km, and between months and decades, illustrated in the top right corner right in *Fig. 228*, may identify their contribution. This finding may indicate the relatively isolated position in technology of Architecture and Urban design. At the end of 2005, the scheme became too small in the bottom left corner by the increasing number of nano-technological studies. The top left corner (nanoseconds at the scale of the Earth) and bottom right corner (millennia at the scale of nanometers) remained empty. There may be some proportionality in our knowledge of the relationship between space and time.

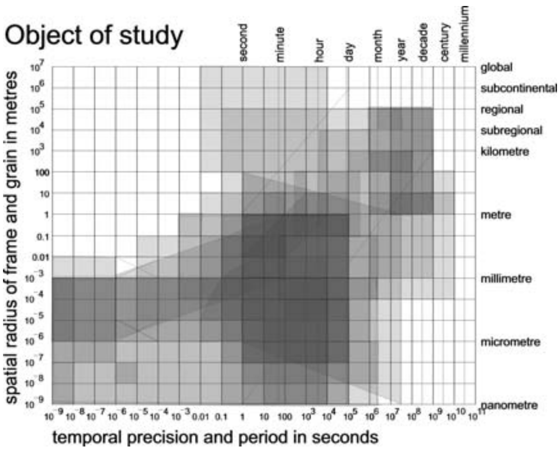


Fig. 228 60 PhD studies TUDelft 2004-2005

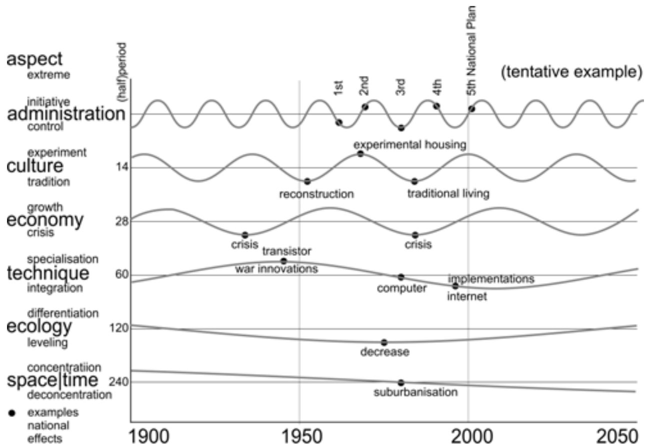


Fig. 229 Different wavelengths per layer

Periodicity in social layers

Fig. 229 shows different periodicities in different physical and social layers. Do not take it too seriously, because if it would depict reality, then the future would be predictable. It is only meant to show the possibility of different wavelengths in different layers. In the political layer, the sinus between initiative and control is depicted with a periodicity of 7 years. It supposes a regular change of administration from an increase of public services into a period of privatisation. In the Netherlands, 5 national plans in 40 years changed from more design into more control, and the reverse. In the cultural layer I suppose a change every 15 years by teenagers protesting against their parents. The fifties in the last century were the years of reconstruction (back to tradition) after the Second World War, but the protest generation of the late sixties caused all kinds of experimental housing, while I remember the eighties and nineties as more traditional. The economic cycle of 50 years is known as the Kondratieff cycle, but the current crisis came earlier than within 50 years. The Schumpeter-Freeman-Perez periods may be more realistic: 1771 > industrial revolution, 1829 > steam and railways, 1875 > steel and electricity, 1908 > petrol and car, and 1971 > information period. *Fig. 230* interprets these cycles as waves with decreasing wavelengths that build upon the previous results.

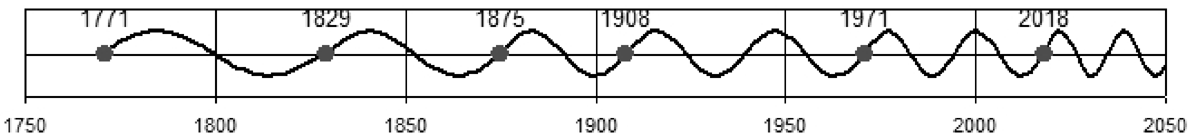


Fig. 230 A free interpretation of the Schumpeter-Freeman-Perez cycle

Periodicity in physical layers

But, both suppose technological shockwaves after rather randomly chosen innovations, in order to fit the economic figures. The technological cycle in and of itself may be an independent layer with an even longer cycle. Its ‘spring’ is the emergence of fundamental inventions, and its ‘autumn’ follows with less inventive practical implementations and combinations. The technology of converting energy, material and information may be crucial. The Dutch expansion in the 17th century was based on peat and wind, the English economy in the 18th and 19th century on coal, and the 20th century the US economy on petrol. The next is surely going to be based on the sun. It was closely related to the chemical conversions of matter (steel, plastics). Breakthroughs in the conversion of information (mathematics, the art of printing, the microscope and telescope, radar, the transistor) were often the result of war. The ecological cycle in *Fig. 229* is more based on what I hope, while the spatial cycle is what I fear. But, the most important conclusion from these graphs is, that the wavelengths can differ per layer. In each layer expectations and intentions may have a different time span.

7.3 Social and physical layers

Interests

Spatially relevant projects require spatial, ecological, technical, economic, cultural, managerial and political support, contributions and resources. The reverse, realisation, will generate positive and negative impacts in these layers. They are divided into specialised sectors, with different time spans and levels of scale. As a designer, you must be aware of the sectors involved, and be able to imagine their possibilities, expectations and intentions. Representatives from these sectors will ask you to balance their interests through design. But, they will evaluate your design against the background of the opportunities and risks for their own interests. As a designer, you have to convince them about the right balance. The selection and sequence of your arguments determine whether it will be convincing or not. The accidental audience determines the most appropriate selection and sequence. If the audience is mainly interested in profits and costs, then you may give priority to the economic arguments. If your audience is mainly interested in the reaction of their voters, then you may give priority to political arguments. But an audience may be composed of different sectors.

The sequence of argumentation

Stressing possibilities, expectations, or intentions requires different sequences, and different language games. As a designer, you may be inclined to stress the possibilities of your design. But, do they also extend the possibilities of your accidental audience? Could local or regional politicians sell your arguments to their backing? Do managers share your optimism in the time and space available? Does the audience share the tacit suppositions of your own subculture of designers? Is it mainly tradition-directed, or is it open to experiments? Are they convinced enough about the profits to accept economic risks? Are there independent technical experts present to share your optimism about the practicability of your design? Could you promise enough possibilities for environmental concerns? Could you please the neighbours of your object with the way you occupy their space? And so on. May be you have to change your language into a game full of metaphors about the possibilities in the direction of the expectations of your audience. Seduce them by realistic prognoses by officials in their field. Warn them of the trends by which they will be behind the times after the realisation of their project. But, the safest way is to study their own previous plans beforehand, to get acquainted with their intentions, and to follow every detail of their brief. Then, you can gradually change your tone into the expectations about the future context, and the possibilities of your design beyond the brief. Let me describe these interests with some irony and exaggeration to remain short in a field I am not very experienced.

Political arguments

Politicians simply determine what we can do together, and what you have to do on your own. Our political representation moves to the left and to the right in a cycle of, say, 7 years. It transports local tasks into municipal, regional, national or international levels of scale, and the reverse. Going right requires removal of public services, going left requires more governmental initiative and consequently higher taxes. The time span covering the realisation of your design and its use, determines the future political context of its existence. Politicians speak the language of desirability, which is a little limited by possibility. They are used to uncertainties, but they are less impressed by probabilities. Civil servants are used to changing the representation of their intentions at the municipal, regional or national level. It is not their fault if they have changed their mind in the next meeting. You serve them best through multi-functional design, or through arguments with something for everyone.

Managerial arguments

Management can be considered short term politics, and at a lower level of scale. It determines what can be contracted out, and what can be done in house. In this case, however, going left requires less managerial initiative, going right the more so. It is a nice example of the scale paradox. The prestige of managers depends upon their capacity to change things within the period of their assignment. The direction is less important. The typical three year manager thus is inclined to make a U-turn compared to the direction of the previous manager, in order to stress what has gone wrong. After six years s(he) then has returned to the situation where the previous manager started, again causing the well-known problems from six years ago. But that phase of the sinus is forgotten by the actual crew. It gives way to the next manager and U-turn. So, if you do not meet the appropriate management for your project, then wait until the next U-turn. The most convincing argument for managers is either no argument, unless it is speed.

Cultural arguments
Cultural arguments range from traditional to experimental, but the most convincing argument is one that causes an increase in recognition, and a little bit of surprise. In this language game, metaphors and references to ancient designs are very useful, even if none of them are recognisable in your design. Culture is the set of shared suppositions in communication. Professionals in this field do not want to show their lack of understanding tacit suppositions. They will mainly object against a lack of references.

Economic arguments
There are two economic arguments: costs and profits. The costs are more predictable than the profits, because of the shorter time span of their appearance. Consequently, your arguments about the profits are less convincing, because speculating about the profits is the main territory of economists. Reducing the costs is the lesser part of their education. So, make your design more expensive than necessary, and let them delete the details you made for that purpose, in order to reduce the costs until they reach the quality you desire.

Technical arguments
Technicians do not like arguments, they primarily want to solve problems. So, give them interesting problems. They solve problems by combining or separating elements of construction. Separation is often more expensive. If that is the case, then separate elements in your design, and let them propose combinations. They then reduce the costs that the economic partners want to reduce. If separations are cheaper, then defend your combinations, and accept your defeat with a smile.

Ecological arguments
Schools of ecology are as diverse as nature itself. Consequently, diversity should be their message, but it is not. Their advise is very homogeneously to save energy, because it saves money and that is what everybody wants. The increase of CO_2 is a great thread for biodiversity indeed, but if saving energy would be the solution, then you should forbid the sun to shine, because it is wasting so much energy. The energy problem cannot be a durable problem, but the remaining CO_2 problem cannot be solved easily through spatial design. Remember, the original task of ecologists concerned biodiversity and human health. They will be grateful. Finally, they will advise diversity, and that is precisely what you can offer them through design.

Spatial arguments
Your colleagues in spatial planning and design may be even more diverse than ecologists. They will object from different levels of scale and time spans in different ways. Show them the picture of the scale paradox of *Fig. 7* on page 21 in order to explain that their adverse advice fits at your level of scale.

Divide and rule
This ironic summary may be perceived as advice on how to manipulate advisors, but it is a counterweight against the implicit uncertainty of their specialised professions. The sequence of their contribution may either successively trim down your plan, or enrich it through the procedure of having to resolve a diversity of conflicting advice simultaneously. Space has the precious faculty to house contradictions.

7.4 Future contexts

Creating a common future

The time span that covers the realisation of your design and its use determines the future context of its existence. The impacts of your design are estimated based on current experience, but they may be different in the future. The expectations of specialists about the future context are different. Exposing them to each other may result in a greater flexibility of their intentions. You may balance their contribution, if you ask them to make their expectations more explicit *before* they have expressed their intentions. If you manage to agree about one probable future, then the estimation of the different effects of your plan are put into perspective. If there are more probable futures, then your design should be *robust* enough to survive them all. Coordinating expectations about the future context avoids premature rejection of your design.

Extreme scenarios

Politicians did not foresee the emergence of nationalist parties. Architects, fashion and car designers did not foresee the emergence of a retro taste. Economists did not foresee an economic crisis. Technicians did not foresee a shortage of rare earth elements. Ecologists did not foresee the appearance of rare species in urban areas. Spatial designers did not foresee the disappearance of shops and the return of work at home by the internet. Their expectations are narrowed by their most recent specialised experiences. Extreme scenarios about *possible* futures may be useful to widen their expectations, their power of imagination and to make their intentions more flexible. But, they are time consuming. Asselt[a] detected 200 scenarios made in the Netherlands in 10 years between 1995-2005. They ranged from world scale to municipal scale, covered short and long time spans, and concerned one or more sectors.

Fig. 231 CPB 2004 scenarios 2040[b]

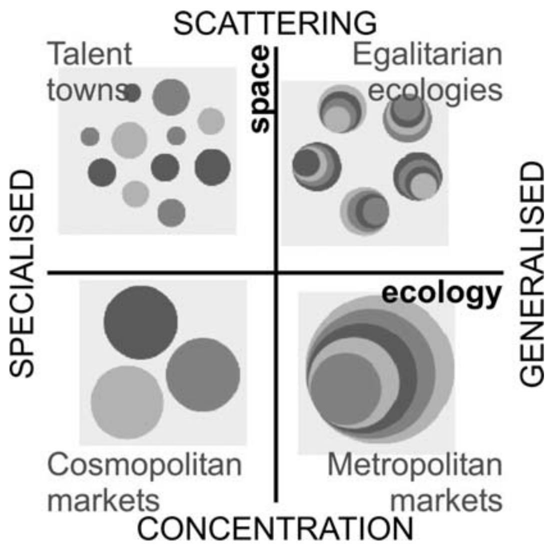


Fig. 232 CPB 2010 scenarios 2040[c]

In 2004 and 2010, the authoritative national 'Central Planning Bureau' (CPB) made four different national scenarios each time, both with a time span to 2040 (see *Fig. 231* and *Fig. 232*)[d]. In 2004, four scenarios were extreme on two axes: the size of the market and political

[a] Asselt;Plas;Wilde(2005) *De Toekomst begint vandaag. Inventarisatie Toekomstverkenningen.* (Maastricht) Faculteit der Cultuurwetenschappen, Universiteit Maastricht

[b] Mooij;Tang(2003)*Four futures of Europe*(The Hague)CPB
Huizinga;Smid(2004)*Vier gezichten op Nederland*(The Hague)CPB

[c] Weel;Horst;Gelauff(2010)*the Netherlands of 2040*(The Hague)CPB

[d] http://www.nl2040.nl/publicatie-deelI-oudescenarios.htm

orientation. In 2010, the axes were extreme on the spatial distribution and 'ecological' task division. The first stressed the national level, the second the urban scale. There are, however, more levels of scale, time dimensions and relevant axes. For example, technology has changed the world more than any other dimension.

Technological extremes

The invention of a usable steam engine (1782), a usable petrol engine (1885) and the transistor (1947) have widened the possibilities of economy, culture, management and politics substantially. Making use of these possibilities has increased their freedom of choice. It has diversified possible futures. It is a serious omission that none of Asselt's 200 scenarios or the CPB scenarios do have a technological axis. But, how to imagine technological extremes at different scales and time spans? The economic axis may range from international expansion into national or local shrinking. It may stimulate a cultural trend into either experimentation or tradition and history. The political axis may range from public to private, resulting in a more active or a more passive management. The 'ecological' axis may range from specialised into generalised. The spatial axis may range from concentration into dispersion. But, how to formulate the extremes of technology, which are a substantial driving force behind all of them? I pondered this question for a long time. The extremes of technology have a relationship with the conversion of materials, energy or information, but these factors do not result in consistent extreme scenarios. Moreover, could you give such factors a different meaning at different levels of scale? How to find an axis of extremes that may differ at different levels of scale? I found a more abstract solution for the technological extremes: separation and connection, division and combination of functions. It results in different technologies at different levels of scale.

Extremes of division and combination

At a world-wide scale (R = 10 000km), anything is 'combined', but the continents (R = 3 000km) may divide their tasks and become specialised by different products of agriculture and industry. This specialisation will determine if there is an intercontinental exchange of shipping products over the oceans. This exchange results in very different technological scenarios. Subcontinents (R = 1 000km) may or may not become specialised, e.g. dividing or not dividing tasks of production or distribution, which again results in very different scenarios, based on different technological possibilities of exchange. States, regions, conurbations, towns and districts of towns may divide their other tasks based on still other technological developments. Traffic systems R = 30m may tend to divide or combine different kinds of slow and fast traffic, building technology R = 1m may tend into division or combination of stress- and pressure-resisting components. And so on, to the scale of chemical division and combination of atoms at the nano-scale. In fact, it is an axis similar to the 'ecological' axis at the urban scale of *Fig. 232*. But ecology does not divide 'tasks', it only shows or doesn't show diversity at any scale level.

More axes and levels of scale

Any axis that is added to imagine different possible future contexts for your project doubles the number of scenarios that need to be elaborated. The two axes of *Fig. 231* and *Fig. 232* produced 4 scenarios. Combining them into 4 axes containing extremes of policy, economy, 'ecology' and space would produce 16 scenarios. But, again adding extremes of technology and culture would produce 64 different scenarios. If furthermore you would take their possibilities at any level of scale mentioned in *Fig. 233* into account, then you would require 5 444 517 870 735 020 000 000 000 000 000 000 000 scenarios. This may be a little bit too much to make your guests aware of a possible future context where the impacts of your design may be different from what they currently assume. But, there is another way to obtain one or more rough perspectives, relevant for your project. Ask every participant what (s)he expects, seen from her or his own position, and take their combined view as your common future, in order to balance their intentions , and put them in perspective. The next section elaborates on a method to do so in a quarter of an hour.

7.5 Balancing intentions[a]

An inventory of possible impacts

The realisation of a spatial object affects external interests positively or negatively. To balance conflicting interests, you can make a rough inventory of intended and possible impacts, even before you start studying or designing the object itself. The programme or brief of your design is nothing else than a summary of the expected positive impacts (see *Fig. 47* on page 91). A summary of impacts suggests which potential partners you should invite for participation or negotiation. You may intend or expect social impacts (governmental, managerial, cultural and economic) and physical impacts (spatial, ecological and technical) at different levels of scale.

Different effects at different levels of scale

Building a sustainable house may cause positive effects for the individual and the global community, but it may spoil the view of your neighbours, and consequently decrease the value of their house. Establishing an industrial plant may provide employment for the region, but it may cause environmental problems in its neighbourhood and exhaust the resources of the Earth. If you upgrade a city centre serving R=3km, then the district centres serving R=1km may decline, giving new opportunities for neighbourhood shops serving R=300m. If you argue that upgrading the city centre provides new opportunities for neighbourhood shops, then, for the sake of convenience, you might overlook the consequence in between, the decline of the district centres. How many levels of scale do you have to check if you do not want to overlook effects at *any* level of scale? If you take *Fig. 7* on page 21 seriously, then the levels of scale must differ by approximately a linear factor of 3. It comes down to 22 levels of scale between the Earth and a grain of sand (see *Fig. 233*).

Global	Continental	Subcontinental	National	Regional	Sub-regional	Conurbation	Town	District	Neighbourhood	Ensemble	Building complex	Building	Building segment	Building part	Building component	Super element	Element	Sub element	Super material	Material	Sub material
10000km	3000km	1000km	300km	100km	30km	10km	3km	1km	300m	100m	30m	10m	3m	1m	300mm	100mm	30mm	10mm	3mm	1mm	<1mm

Fig. 233 Relevant levels of scale (expressed in R) to check possible impacts

The named radiuses R={10 000km, 3000km, 1000km, …1mm, <1mm} are not exact measures, but 'nominal values' as explained in *Fig. 17* on page 52. They may overlap.

The object and its context

Fig. 234 represents a building complex in its context. This *object* is represented in the (spatial) bottom layer as 'O', ranging to 'o'. The rest is *context*. 'O' is the frame (R=30m) of the building complex. Anything larger is context. Its grain 'o' (r=300mm) is the smallest component taken into account. Anything smaller (e.g. building materials) is also 'context'. Even if you do not know the impacts of the intended building complex and its components in this context exactly, you may have an idea whether there will be governmental, managerial, cultural, economic, ecological or spatial impacts at different levels of scale. You may only *locate* them in the layers and levels of scale where you expect *any* impact, even without specifying them. Positive impacts may become part of your programme (P in *Fig. 234*).

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[a] Parts of this section were published earlier in Jong(2007) *Context Analysis.* **IN** Bekkering;Hauptmann;Heijer;Klatte;Knaack;Manen**,** *The Architecture Annual 2005-2006. Delft University of Technology* (Rotterdam) 010 Publishers p92-97

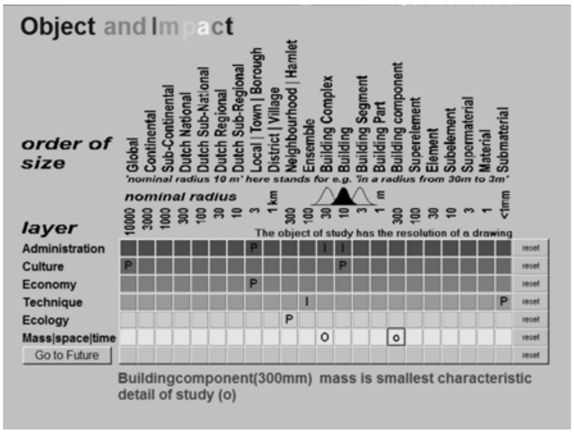


Fig. 234 Locating impacts (I) and positive impacts (P) as a programme of object O...o

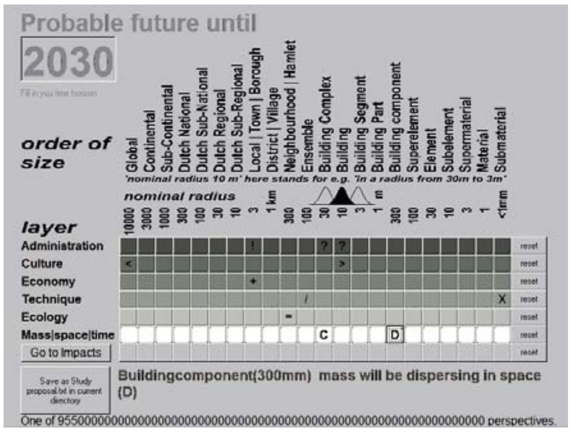


Fig. 235 Making expectations about the context of these impacts in 2030 explicit

You may invite representatives from the indicated positions to discuss your project. Ask these clients, partners, stakeholders and those having any other interest in your object whether they expect positive (P) or uncertain (I) impacts. This delivers a set of possible impacts in the context of your object.

Future context

But, the impacts will be different in different *future contexts*. For example, any impact will be different in a context of growing economy compared to a declining economy. Therefore, you may ask your guests their view on the future, based on their position, in the given time span. *Fig. 235* shows an example of which future they could expect in any position. At different levels of scale, the government or management may be active or passive, the culture may be innovative or traditional, the economy may be growing or declining, the technique may develop more divisions or more combinations, the ecology may be diversifying or equalising and objects (mass) in space may concentrate or de-concentrate. In fact, you make a scenario, based on views from the different positions involved. If you do not agree about one scenario, then you can make more scenarios.

Impacts depending on a probable future context

If the expectations about the probable future within which your object will have its impacts are clear, then you may specify these impacts in this context further. They may raise new intentions at the different positions, as they are coordinated by a common scenario. It is important to be explicit about these expectations, because people with other future contexts in mind will judge your initiative with other suppositions about the probable future. They can reject your study solely on that basis. If you have made your suppositions explicit beforehand, you can ask them to judge the qualities of your study or design again, but now within that perspective. It could raise an essential debate about the robustness of your study in different future contexts. So, it can be evaluated also against the background of different, but determined perspectives.

The FutureImpact computer program

To agree with stakeholders and specialists beforehand about a common vision on supposed futures, I developed a simple computer program called ‘FutureImpact’[a]. ‘FutureImpact’ can be used by individuals or groups. The program delivers a more precise division of orders of size and layers, as shown in *Fig. 47* on page 91, through the use of separate buttons. They allow to chose two very rough extreme values per button to maintain an overview (see *Fig. 234*). In the second screen (*Fig. 235* left below) you will find a button that produces text in

[a] Downloadable from http://team.bk.tudelft.nl/Publications/FutureImpact.exe or http://team.bk.tudelft.nl/Publications/FutureImpact.zip

the map where you stored the program. It is a text to be elaborated into a report or study proposal. It contains all given the inputs at any level of scale and layer already systematically divided in chapters and paragraphs. Once you have located possible impacts, the future context of these impacts determines their possibility of realisation. For example, if you suppose desirable impacts in municipal administration (R = 3km, see *Fig. 234*), how then, could you estimate their value without any supposition about their future managerial context, in the period these impacts should be realised (e.g. until 2030 chosen in *Fig. 235*)? Is it an active management context with many initiatives, or is it a passive administrative context that just checks and controls the rules? In the last case, other initiatives should be part of your own project, in order to have the intended impacts realised. The same applies to the administrator of the building complex (R = 30m) and the users (R = 10m). And, these impacts can be opposite at these different levels of scale.

Roughly typing the social future context

The computer program follows the distinctions from page 256. For administration and management, it distinguishes opposites of initiative ('!', as symbolised in *Fig. 235*) and checking and controlling '?'), applicable at any scale level. There are many other possibilities to type administration and management style, but this variable hits the core of management itself, in that it is relevant for design and applicable at any scale level. But what about culture? For example, what does culture mean at the level of building material (R = 1mm)? To include any scale level, the program distinguishes 'traditional' (<) opposed to 'innovative' or 'open to experiments' (>). For example, if your study will have impacts on households (R = 10m), and these households are mainly traditional, it will be difficult to confront them with an experimental design. However, if your client is an innovative housing corporation (R = 1000m?), you will get support from that side. That cultural context will influence your study and your presentation, and the way you will arrange your arguments. The economic context has been characterised minimally through growing (+) and declining (-). That can be different at different levels of scale. The economic context could be a declining neighbourhood within a prosperous municipality. A context like that will determine a project or an assignment to a considerable extent.

Roughly typing the physical future context

Which extremes could be found to characterise the technological context at any level of scale? According to the distinctions from page 256, the program allows to choose internal separation (/) and combination (X) of functions as relevant and essential technological context values. It is also an essential design choice at every level of scale: shall I separate or combine pressure and tension (R = 10cm), separating and supporting functions (R = 1m) within my construction, cook and eat in my kitchen (R = 3m), live and work in my neighbourhood (R = 300m)? If the probable trend is to combine living and working at a district level (R = 1km), then you still can separate it at the level of the neighbourhood (R = 300m) or the building complex (R = 30 m). That kind of expected context is important for any design decision.

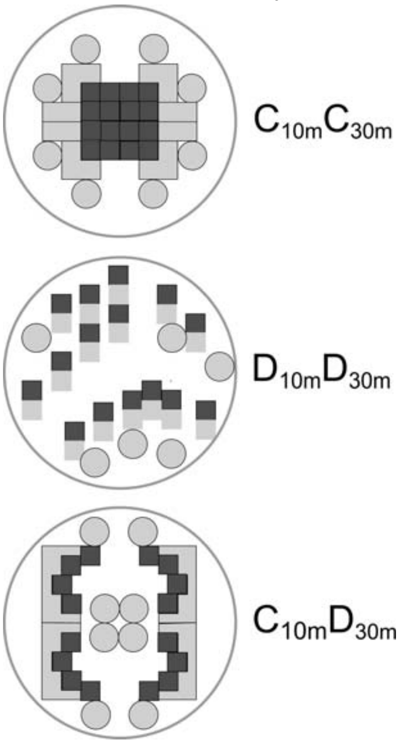
In ecology the program allows to choose diversity or heterogeneity (|), as opposed to equality or homogeneity (=). Which kind of diversity it concerns could be elaborated later: diversity of plants, animals, or people, households with the same or different age, lifestyle or role-emphasis (e.g. familism versus careerism).

At the purely physical level of mass and space in time, accumulation, concentration (C) of masses versus sprawl, and de-concentration (D) are essential design context factors. What is called mass could be specified later, but concentration and de-concentration (state of dispersion) of legend units in a drawing are characteristics of form and composition at any level of scale. They can differ per level of scale (see *Fig. 236* and *Fig. 237*).

An existing or expected scale sequence like DCDC or its reverse CDCD (concentration accords) identifies some global characteristics of form. I will elaborate on the 'state of dispersion' more in detail, because it is relevant in other layers as well.

States of dispersion

Form as a primary object of design supposes a state of dispersion of an arbitrary legend unit, e.g. built-up area. Scale articulation is important to distinguish states of dispersion. That is not the same as density. Considering the same density, different states of dispersion are possible (*Fig. 91*) and that is again the case at every level of scale (*Fig. 95*). *Fig. 91* shows the use of the words concentration (C) and de-concentration (D) for *processes* into states of more or less accumulation, respectively. When applied to design strategies in different levels of scale, I would speak about 'concentration accords' (*Fig. 95*). In *Fig. 95* the *regional density* is equal in all cases: approx. 300inh./km^2. However, in case CC, the built-up area is concentrated at both levels ($C_{30km}C_{10km}$) in a high *conurbation density*: (approx. 6000inh./km^2). In the case CD, people are de-concentrated only within a radius of 10km ($C_{30km}D_{10km}$), into an average conurbation density of approx. 3000 inh./km^2. In the case $D_{30km}C_{10km}$, the inhabitants are concentrated in towns (concentrations of 3km radius within a radius of 10km), but de-concentrated over the region. Since 1966, this was called 'Bundled de-concentration' (RPD, 1966). The *urban density* remains approx. 3000 inh./km^2. In the case $D_{30km}D_{10km}$, they are dispersed at both levels.



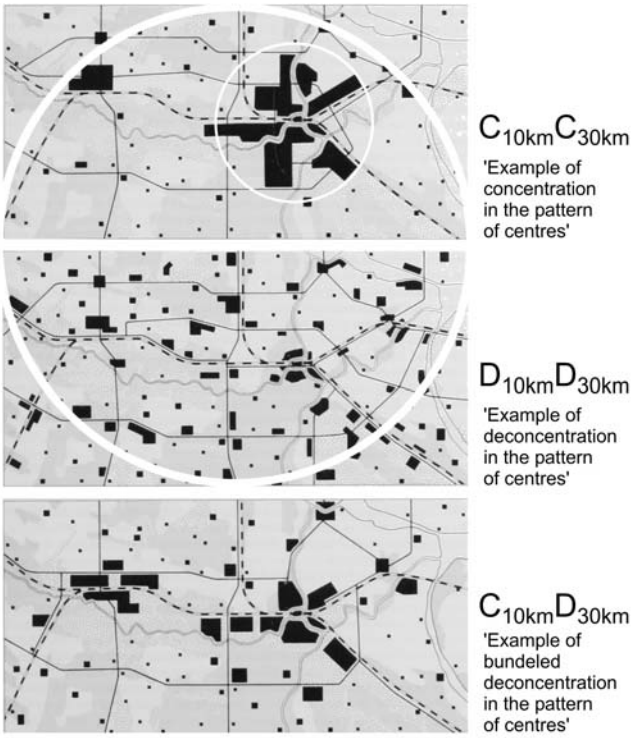


Fig. 236 States of dispersion R=30m

Fig. 237 Accumulation, Sprawl, Bundled De-concentration R=30km[a]

Desirable, probable and possible future contexts

There are three language games ('modes') concerning the future context that are relevant for urban, architectural and technical design, and their stakeholders and specialists (see *Fig. 1*). By not distinguishing these modes of future, a confusion of tongues between stakeholders aiming at *desirable* futures, and specialists predicting *probable* futures and designers exploring *possible* futures, results. Distinguishing them properly can deliver an outline of fields of problems and aims that should be taken into account.

Subtracting probable and desirable futures

Probable futures we do not want are a field of problems (see *Fig. 238*). Problems are predicted or signalled through specialists' empirical studies.

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[a] VROM(1966) *Tweede Nota Ruimtelijke Ordening* (Den Haag) Staatsuitgeverij

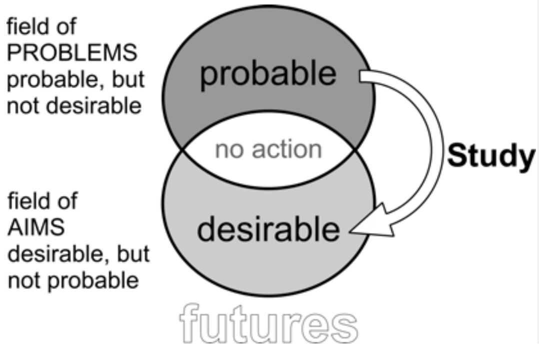

Fig. 238 Subtracting futures into fields of problems and aims

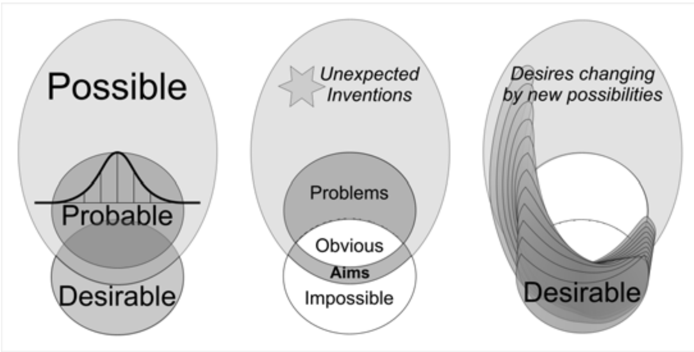

Fig. 239 Adding possible futures, changing desires into unexpected possibilities

Desirable futures that we do not expect to happen without action (like desirable but not probable futures) are a field of aims. Clients, stakeholders and their representatives (administrators, managers) deliver a field of aims. Sometimes it is a battlefield. Often not all of them are possible in one project. The designer guards and extends the possibilities through design.

Adding possibilities by design

Anything probable is per definition possible, because if something is not possible, it certainly is not probable. But not all possible is also probable (see *Fig. 239*). There are improbable possibilities. To find these improbable but possible futures (including and using the many probabilities of specialists as possibilities) is the task of the designer. S(he) is supposed to know many possibilities that stem from design and typological research (see *Fig. 50*). Sometimes s(he) adds possible futures no one in the team could imagine, let alone desire beforehand. Their desires and aims that were embodied in their program of requirements, were limited by their imagination. Desires can change as soon as new possibilities are imagined. That is why design can change a program of requirements.[a]

The context of invention

The designer has a personal context that is relevant to be selected for, or to propose, a specific design study. It contains her or his field of abilities (portfolio, own work) and field of design means (repertoire, studied references to the work of others). S(he) is supposed to have gathered many preceding examples (precedents), and to have studied them by design research and typology (see *Fig. 50*). They should explore the design possibilities by pulling them out of context, and processing them into a new context.[b] S(he) is supposed to be able to apply, process and extend them in a given context, which can be proven through their portfolio of work. Of course, s(he) is moulded and limited by education, colleagues and friends. But the available portfolio and repertoire can be included in a study proposal for possible futures in a more or less determined context.

Limitations of a design related study proposal

To make a study proposal, teachers and clients often ask a clear cut problem definition and clear cut aims, a hypothesis, an overview of methods to reach the aims that are tested by the hypothesis, a planning of time and means (data!) and a list of expected results. I suppose that my proposal to weaken the problem~ and aim definition into a broader *field* of problems and aims will meet objections: “Without a clear problem~ and aim definition, any scientific study becomes boundless!” That is an objection that typically stems from the

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[a] Weeber;Eldijk;Kan(2002) *Designing a City Hall* **IN** Jong;Voordt, *Ways to study and research urban, architectural and technical design* (Delft) Delft University Press

[b] Hertzberger(2002) Creating space of thought **IN** Jong;Voordt**,** Ways to research and study urban, architectural and technological design (Delft) Delft University Press

practice of empirical research, which focuses on truth or *probability*, and aims at *desirability* (see *Fig. 238*). However, a design related study focuses on *possibility* (see *Fig. 239*). In the field of urban, architectural and technical design or management, there are other general limitations that prevent a boundless study. To the weakened 'fields' of problems and aims, a scale, a repertoire and a portfolio can be added. These five limitations can be gathered from a proper context analysis when introducing the proposal. More than in empirical research (principally repeatable by others), in design study (principally not repeatable by others) the field of abilities and means of the person executing the study are relevant for the expected result. Once these fields are presented, you can choose two different directions of study: elaborating on these fields to improve them, or explore new fields of design means and abilities. Both are legitimate, but their results are inherently different, and should be mentioned at the beginning of the study proposal.

The content of a design related study proposal

The limitations of empirical research result in problem isolation that is not suitable for studies related to context sensitive urban, architectural and technical design or management cases. That kind of study can utilise other limitations to prevent a boundless study project: a determined scale (frame and grain), the field of design means (repertoire) and the field of abilities (portfolio) of the person executing the study. By adding these limitations the ceteris paribus isolated problem~ and aim statements can be broadened into the description of a *field* of many coherent problems and conflicting aims, to be recapitulated in a concept. To provide for these limitations, a design related study proposal should be preceded by a context analysis that contains many elements that are otherwise dispersed in the proposal. So, the proposal itself can be short. Such a context analysis is possible even if the object of study is still variable beforehand, like a design. For example, the contents of a study proposal then could be as follows.

1 CONTEXT ANALYSIS
1.1 Object of study: time span, frame and grain
1.2 Probable future context: field of problems
1.3 Desired impacts of study: field of aims
1.4 My references and repertoire: field of means
1.5 My portfolio and perspective: field of abilities

2 STUDY PROPOSAL
2.1 Location or other future context factors
2.2 Motivation or program of requirements
2.3 Intended results, contributions and planning

3 ACCOUNTS
3.1 Meeting criteria for a study proposal
3.2 References
3.3 Key words

The last button of the FutureImpact computer program produces a text with these chapters, asking many questions that require user input, in order to elaborate on solutions in greater detail. The sections 1.1 – 1.3 are already elaborated according to *Fig. 238*, through the automatic subtraction of the probable and desirable futures that were provided via user input. That text should be modified by the user thoroughly, it is nothing more than a checklist, with many suggestions for elaboration, according to the given input and the method proposed here.

8 Possibilities for education and study

8.1 Education

Entering a new culture

Education introduces people to a new culture. A culture is a set of shared suppositions. If your students do not share any of the suppositions you to start with, then your teaching will fail. If there is not a sufficient common culture (such as a common language, a shared distinction of subjects, some awareness of their relevance, their separations and connections, some values of mutual behaviour or other self-evident background such as primary mathematics), then there is no basis for successive advancement for the next steps. Without the preceding suppositions you usually take for granted yourself, you cannot expect your students to understand the next conditional, logical or causal step, because it is based on preceding steps. They will not ask you about your tacit background, because they are either (wrongly) ashamed, or simply because they *cannot know* what to ask (Meno's paradox). They will miss a step and stay behind.
Education requires a conditional sequence of steps.

The art of educating

The art of educating is the art of recognising your own tacit suppositions. Some of your suppositions that are essential for the course, may be different from those of your students. Omitting bridges between concepts, or ignoring gaps or barriers, results in a silent misunderstanding or loss of attention and interest. It is not easy to estimate what your students suppose rightly or wrongly, and what they do not suppose at all. Telling what everybody already supposes is as disastrous as not telling what has to be told first. In the classes that contained students from many cultures, I used to count how many students yawned and how many had glazed looks, and I would accelerate or slow down my lecture accordingly. It is of course better to let them speak, write or draw first, and carefully examine what each of them may miss, avoid, or wrongly suppose. But that is time consuming, and not easy. Students may be inclined to avoid the gaps and barriers by applying safe, traditional solutions, without even being aware of other possibilities. You, then, still cannot conclude what they miss or wrongly suppose to be able to solve *non*-traditional problems, and to find *improbable* possibilities. Some wrong suppositions may be hidden so early in the conditional sequence of suppositions, that you even cannot imagine them yourself.

A conditional sequence of suppositions

Even if you are fully aware of the suppositions you do not share with your students, you still have to explain them in the right sequence. In specialised disciplines it is easier than in a design education to know what you need in the Bachelors to be able to understand and to succeed in a Masters program. *Design* education requires you to *integrate* the contributions of many specialists that speak many different (mainly linear) languages. It requires a student's *awareness* of their existence, their field of knowledge and know-how (without sharing with them completely), their relevance in different cases and an *ability* and *daring* to ask specialists the right questions, and to express her or his doubts in *their* language. Their possible contribution, their jargon and the relativity of their advice may be obvious for you, but not for your students. They may take them too serious or not serious enough. It is difficult to find a balance between too little details to keep in touch with specialists, and too much details to maintain an overview perspective. And, a design is much more than combining specialist contributions. It requires a *productive* mode of thinking, which is very different from the specialist's *reducing* possibilities into truths and probabilities. A specialist cannot make this switch easily after years of education, and also because they are respected just *because* of her or his authoritative knowledge in a field of proven truths and probabilities. The core of *design* is to imagine possibilities *beyond* anything existent or probable. How to teach that kind of imagination? Imagination in and of itself has a conditional sequence of suppositions. It starts by *distinguishing* things that are imaginable next to each other in time (to find *causes* that make things probable) or in space (to find *conditions* that make things possible). This thesis may have given some suggestions for spatial distinctions: distinguish outward and inward directions, distinguish levels of scale, and distinguish what is probable from what is possible. But, let us first clarify the time- and action-based specialist expertise that should be transferred to an education of designing the *environments* of action.

Truth finding by specialists

'Knowledge' is a set of tested suppositions about limited parts of reality. In a pragmatic sense, suppositions are called 'true' if they repeatedly have supported our intentions and actions better than previous suppositions. Scientific knowledge convinces best, if the knowledge is the most successful basis of economy, culture, education or even justice, and if it enables more people to survive than ever before. The empirical method of truth-finding is convincing through the social success of:

1. concentrating on isolated, conditioned, but repeatable observations,
2. freely generalising them in readable suppositions,
3. freely publishing both in a refutable way,
4. to be checked freely under the same conditions by other people.

Empirical research may falsify useless or even harmful suppositions as 'mistakes', 'misrepresentations', 'myths' or even 'lies', showing ignorance, credulity or even deceit. Education should particularly challenge these suppositions. But, compared to the inconceivable diversity that *could* be observed, scientific knowledge still covers a tiny selection of reality. The possibility of generalisation outside this selection is commonly accepted, but it is only a shared, repeatedly successful supposition. The selection itself is influenced by existing categories of communication, words, and variables. The inward categorisation of the initially observed diversity, and its outward generalisation into other contexts, have become suppositions that are silently recycled in any empirical cycle. You cannot easily criticise suppositions other than using those categories. Your criticism beyond the common vocabulary cannot be understood. The critique then often remains immanent. You cannot easily withdraw from these tacit categorisations and generalisations in a deafening acoustic feedback of commonly accepted citations.

Inward specialisation, outward generalisation

Differences are generalised in words, language and theories *as if* they were equal, waiting for the next falsification by new observations. The 'same' atoms appeared to be different as isotopes. The 'same' molecules appeared to be different *drawing* them as isomers. The 'same' species appeared to be different as subspecies, races and characters if you took a closer look. Any discovery is focused on distinguishing more differences mainly *within* existing categories (immanently)[a], raising more questions about their relations, and more problems to be solved by an ever larger multitude of specialised disciplines. These disciplines continuously have to extend their nomenclature. After 3000 years studying our own species we now need at least 29 medical specialisations, and still, we 'know' little about ourselves. With our increasing knowledge, our awareness of what we do *not* know seems to increase. Scientific effort is motivated as 'truth-finding'. But, what is 'truth' if it is not

[a] Kuhn(1962) *The structure of scientific revolutions* **IN** Neurath, O.; Carnap, R.; Morris, C. *The International Encyclopedia of Unified Science* (Chicago) The University of Chicago Press

complete? Without specified context, and its scale (ceteris paribus), it is 'half truth'. If 'context' encloses every level of scale, then even anything differs, and generalisations that ignore context may become doubtful for designers in practice.

Possibility search by design

Incorporating the contributions of every specialisation involved in a design, requires 'possibility-finding' *outside* their limited subset of 'truths', or their approximations, called 'probabilities'. The larger set of possibilities, however, is even more diverse than its subset of probabilities. The usual categorisations of scientific knowledge that are expressed in generalising words, and in strictly sequential texts or theories, do not provide a sufficient understanding that allows designers to find new possibilities. To invent new possibilities, you still may use many existing suppositions, otherwise you get lost. But, creativity is *skipping* at least one commonly shared supposition. It may open a view on what is behind that barrier. Design education then should include exercises skipping common suppositions. Carel Weeber once assigned his students to design a customs office on the Moon between two countries inhabited by people of substantially different size. Skipping usual suppositions (e.g. about size, gravity, day length, light and atmosphere) is required to liberate imagination.

A dialogue with your drawing

Imaginable objects cannot always be expressed fully in a linear language with equalising categories connected by verbs. If we restrict ourselves to spatial design, then a two-dimensional drawing shows relations perpendicular to the direction of a linear representation: the side roads and views from its main road. The character of side roads, side views and their possibilities may be different, contrasting, opposite or even contradictory to the main course of a text. That pictorial con-text shows the many *possible* relations of different kinds and scales. You primarily discover and invent them by the act of drawing itself. Expressing your imagination in a drawing produces unexpected effects that were not yet present in your previous imagination. You may improve it, emphasise some, and weaken others. The motoric act of your hands may add tacit suppositions to your idea. Mistakes may become advantages, as mutations did in evolution. The feed-back from what you expressed in a text or a drawing may change your thoughts about possible processes and patterns. A text *tells* a story, but a drawing *accommodates* a multitude of possible stories. The feed-back of drawing is two-dimensional, multi-directional, but scale-bound. From a viewpoint of improbable possibilities, usual categorisations may shift through the act of drawing. In an initial drawing, their boundaries may change into non-verbal distinctions not yet specified by words or a legend. This is the creative point where you may skip usual suppositions about content, form, structure, function and intention.

Conditional sequences of imagination

It has taken many years before you could imagine a possible reality behind a design. The number of suppositions you have built upon each other to reach this level of imagination exceeds the number of words in your vocabulary. Piaget's 'tableau mouvant' of differences, and different changes you probably have experienced shortly after your birth, still had to be separated into objects that were moving faster than their relatively stable background before you could connect words to them. Your first year must have been filled with parallax experiments to connect your experience of own *movements* with the changes you could *see*. This connection should have been constructed before you could distinguish separate objects nearby and further away. Your recognition must have been developed by connecting returning objects with the objects you remembered as imaginations, even if they were absent. These imaginations subsequently must have been connected with the returning *touch* and *sound* experiences that accompanied their appearance before you could *grasp* them by your own movement, and name them by the same *sound*. Many more conditions must have been fulfilled before you could simulate your touch by drawing them. Drawing supposes coordination and *direction* of movements to grasp what you have in mind, and to select what you want. Selection supposes (⇓) connection ⇓ separation ⇓ change ⇓ difference, to name only *some* necessary conditions of imagination (see *Fig. 222* on page 242 and *Fig. 240* below). You have constructed your imagination step by step, by passing these stages your own way. You have simulated your progress by building towers and playing with blocks. You may have experienced how difficult it is, to change the lower blocks to make a larger tower possible. Changing suppositions is at the core of design-education's aim of expanding a student's power of imagination.

influence ⇓	production ⇓	selection ⇓	probability ⇓	management ⇓	intention ⇓
involvement ⇓	organisation ⇓	connection ⇓	possibility ⇓	culture ⇓	function ⇓
identity ⇓	specialisation ⇓	separation ⇓	**imaginability**	economy ⇓	structure ⇓
expression ⇓	regulation ⇓	change ⇓		technique ⇓	form ⇓
imagination ⇓	consumption ⇓	**difference**	(overlapping)	ecology ⇓	content ⇓
			desirability	**space**	**scale**
Conceptual ⇓	*Biotic ⇓*	*A-biotic*	*Modes*	*Layers*	*Orders*

Fig. 240 Outward conditions

Fig. 241 Inward conditions

Modes of reason in a conditional sequence

Fig. 241 shows other selections from the numerous suppositions you once may have passed in a conditional sequence. They are chosen as other milestones, placed in the same sequence as they are used in this thesis for different purposes. The sequence is determined by a simple introspective test: 'could you imagine A without B, but not B without A, then B is supposed in (or conditioned by, made possible by) A'. Since it is necessarily an introspective test, the right sequence is open to discussion. It would take a long time to put any pair of words, categories or even non-verbal suppositions to this test, but the sequences given in *Fig. 240* and *Fig. 241* may be used as preliminary checklists for education. The terms printed **bold** are starting points that do not require further suppositions. I cannot imagine probable futures without possible ones, but I can imagine possible futures without probable ones. It is even the task of designers to imagine improbable possibilities. Possible futures are not imaginable if you cannot imagine them, but the boundaries of imagination cannot be drawn, because in that case you would have to imagine what is outside the imaginable (an argument derived from Wittgenstein). But, you can establish that some people possess more imagination than others. Imagination can be extended. For design, however, they also have to be limited to what is possible, and this can be concluded only by realisation. The fourth mode of desirability overlaps probable and possible futures (see *Fig. 2* on page17), sometimes even exceeding the possible as an imagination of the impossible.

Layers of function in a conditional sequence

The 'layers' of *Fig. 241* express a sequence of 3 social layers, supposing 3 physical layers in a conditional sequence of 'functions', as assumed in section 6.3 on pages 225, 229 and 230. A failing management may indicate a failing execution of its tasks, but it also may indicate lacking underlying conditions to fulfil these tasks: a lack of culture, economy, technology, ecology or space. I cannot imagine a management without a set of shared suppositions (authority, appointments), a culture. I cannot imagine a culture without a sufficient economic basis to survive. I cannot imagine a modern economy without an operational technology, a supporting ecology, enough space, time and materials. You may object, that it is the very *task* of any management to manage and to take care of these functional conditions. But, this *probable* downward *causal* effort (see *Fig. 242*) is only *possible* by a minimal fulfilment of functions in an upward *conditional* direction. Moreover, these conditions determine the *priorities* of management prior to the execution of its plans. A manager may conclude that the 'culture' of an enterprise does not function according to its aims. (S)he then may propose cultural measures to improve its performance. But, if the employees use outdated computers or machines in ill-ventilated, dark and narrow rooms, a manager may better improve these preceding conditions first, before accentuating less basic demands.

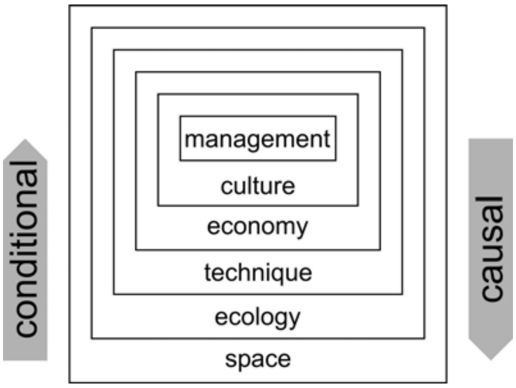

Fig. 242 Layers inward and outward

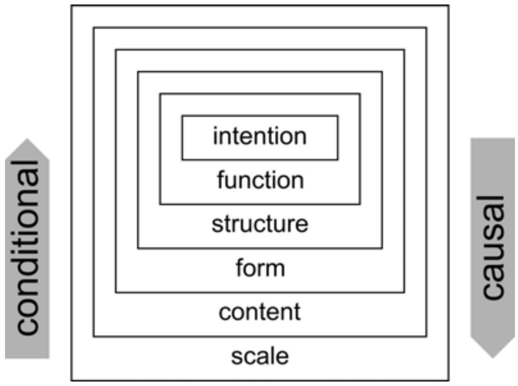

Fig. 243 Orders inward and outward

Orders of difference in a conditional sequence

A spatial designer must be aware of these functions, but it is not the task of design to determine them by *causal analysis*. Rather, it is their task to make them possible through *conditional synthesis*. This switch from reductive analysis into productive synthesis is apparently so difficult, that these tasks are divided between managers and designers. Managers are specialised in talking, time, *changes*, strategies, tactics and flow schemes. Designers are specialised in drawing, space, *differences*, conceptions, types, scale-models. But, just as managers have to be aware of *conditions* to choose their priorities rationally, designers have to be aware of *causes* to decide how to start designing in a given context. A designer has to cope with a *field* of problems (usually covering a larger time span than those of management). (S)he has to find a direction in that field, balancing between future needs and possibilities (see 7.1 on page 245). Some of the problems may be solved better at an other level of scale than the assignment suggests. That could change the assignment. “Why a canteen if there is a restaurant next door?” “Why a central garden if you can make a green balcony for every room?” Possibilities can change needs. Designing is not merely following the required functions stemming from traditional imaginations of probability specialists. It also may produce possibilities that change the intentions of the client. There is an inconceivable diversity of possible contents, forms and structures to choose from. Many of them can serve the same brief. Any of them adds affordances that are difficult to formulate in words. They may become important as soon as the client has to change its use or to sell the object before it has to be demolished. Some multi-functionality improves a building’s resale value and client attraction. But, even for a brief with a very strict programme of functions, there is still an inconceivably larger diversity of possibilities than the available traditional solutions. How to cope with this diversity? In the daily practice of design, with its time pressures, it may be wise to start analysing the intentions of your client and its traditionally formulated functions, to study some successful existing examples and to combine their partial solutions into a new solution fitting the given context. You may even decide to join a building industry to limit your design possibilities further into the most economically executable solutions available, offering the client an ‘integrated design’. It is the ‘causal’ way in *Fig. 243*. But, is it also the best way for design *education* aiming to extend their students’ ability to explore possibilities, and improve the power of their imaginations? The content of this thesis follows the opposite way to stress imagining possibilities instead of probabilities.

Design methods

Your design starting point may differ in different social and physical contexts of design practice. It may result in a different design method each time. If the location, the required functions and the intentions of your client are strict and clear, then the ‘functionalist’ approach may be the best. If the form simply follows the stereotypes of function according to the imagination and expectations of your client, then it is also the least time consuming method. It avoids risks. It becomes innovative if you deviate from these stereotypes, or if new functions appear. Even a functionalist designer has to explore the other possibilities of structure, form and content, if there are no examples. The 'structuralist' way is mainly motivated by the intention to relate to the human scale. It aims at a particular kind of structure: smaller separated parts connected into a whole. It starts lower in the sequence of *Fig. 243*. But, if it does not pay much attention to these separations and connections in the beginning, then it starts even lower. It then may be named better as 'compositional design', because it starts studying a 'form' that is clearly articulated in components at a human scale. In practice, you may choose any level of *Fig. 243* as a starting point, depending on the context. But the higher the level, the more tacit suppositions about the lower levels play a role, and education should start with the least number of suppositions possible.

Design education starting by scale and content

This thesis suggests to start exercising design at different levels of scale, e.g. R = {30, 10, 3, 1, 0.3, 0,1km}. An exercise to make them all successively, will make students aware of the different content of each level of scale, expressed in a slightly changing legend. Suppose, you divide 20 students into four sector-groups called 'Red' (housing), 'Green' (nature), 'Yellow' (business) and 'Black' (infrastructure). You lay down a plasticised 2.4 x 2.4m map, representing a region R=30km (see Fig. 245). You give each group stickers r=1.2cm (300m) in their colour. The number they get fits the expected extensions in the region for the next 30 years. Any sector group gets 3 minutes in turn to glue their stickers on the map according to the interests of their sector, until all are used (see Fig. 244).

Fig. 244 *Students making a dot map 1:25 000 2030 with stickers r=1.2cm(300m in reality).*

Fig. 245 *The R=30km region Veluwe-Arnhem-Nijmegen to be filled with dots*[a]

Within one hour, the result is a 'laissez-faire map' of the region, filled with the extensions you may expect if there were no planning. The students evaluate the result and write down the general impacts, and the impacts that are specific for their sector. The next day they meet to discuss what they have to study to make a better plan next week, and divide the tasks. They make alternatives for their own sector, in order to discuss them with the other sectors. At the end of the week, they meet again to choose the best fitting sector alternatives, and to discuss how to make a better plan through coordinated planning.
The next week you repeat the exercise, resulting in a *planned* design for the region. Every student makes a personal report comparing both plans, and chooses an R = 10km part counting the glued surfaces, in order to make a more detailed design according to these surfaces for that part individually. The individual R = 10km plan is detailed until r = 100m (the grain of the drawing), with a further differentiation of the legends. Every student presents her or his plan in the third week. Next to that plan they make a report of the problems they met,

[a] CityDisc(2000) Den Haag

and criticise the decisions of the previous R = 30km regional plan.
This procedure is repeated in week 4, by detailing R = 3km until week 7, where they detail R=100m. After 7 weeks, every student has made 5 designs at different levels of scale evaluating and criticising their previous design decisions, and developing the legends appropriate for different levels of scale.[a]

Design education of possible content and form

The dot map of Fig. 244 shows how 'form' can be interpreted as 'distribution in space' of some content. *Fig. 74* on page 114 shows possible contents as spatial variables with values at different levels of scale. The columns of the table show which variables may deliver values useful as legend units in a radius R = {1, 3,…300m, 1, 3,…300km}. There are, however, many more spatial variables possible, and there are singular legend units not fitting in an ordinal range to be named as a variable. A variant of the exercise above uses other predefined, but rather unusual legend units to obtain a different interpretation and image of areas at different levels of scale.[b] A simple exercise that would stimulate imagination begins with choosing a radius, an existing area of that size, and two suitable variables, in order to make a design that varies the values of these variables. The design thus will have a legend based on these variables. You may ask several questions about such a design, e.g.:

- Are the successive values of one imaginable variable gradually changing in space?
- Could you imagine more legend units as values fitting in the same variables?
- How could you describe the environment *between* any pair of legend units?
- How many kinds of boundaries are possible, and how many are realised?
- What is their length compared to the shortest length possible (boundary-richness)?
- What is the character of these boundaries (see *Fig. 52* on page 98)?
- Is this character direction-sensitive?
- How could you describe the distribution in space (see *Fig. 95* on page 161)?
- What is the total and average surface covered by any legend unit?
- Are the possible distributions limited by the character of the variables?
- Is there an implicit or possible relationship with other variables?
- Could you identify different components in the composition of the drawing?
- Could you characterise these components (see *Fig. 65* on page 102)?
- Does this characterisation suggest other variables of a larger scale?
- Could you draw some characteristic and connecting details (*Fig. 65* on page 102)?
- Would the distribution and composition be stable without additional measures?
- Which connections and separations would you propose between any location?
- Is the distribution in space as proposed in the design operational for any use?

You may add questions about the distribution of lines (see 0 from page 164 onwards).
If the design concerns the smaller radiuses R = {1, 3,…300m), then the third dimension plays a crucial role. The vertical direction may show other variables than the horizontal ones. You may extend the number of variables of the exercise.

Design education of possible form and structure

A composition divided into components and details may suggest 'structure', but structure as intended in this thesis has to be distinguished from 'composition'. It is an additional set of separations and connections to stabilise, to realise and to use the form in the sense of 'construction'. It deserves separate attention concerning potential movements, such as collapse or other undesired flows that disturb the form and its use. Structures in three

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[a] An elaboration of this exercise in Dutch is downloadable from http://team.bk.tudelft.nl/Publications/2001/Jong(2001)ModuleGrondgebied(Delft)BkUrbanismS4.pdf.
[b] A variant of this exercise in English using predefined legend units is downloadable from http://team.bk.tudelft.nl/Publications/2002/Jong(2002)DesignAndTechnique(Delft)BkUrbanismMSc1.pdf.

dimensions introduce detailed problems of mechanics and physics of flows. They require necessarily specialised parts of design education. But, they include structures already present and imaginable in a two-dimensional drawing through plain maps, floor plans and cross-sections, which are ex-*plain*ing the third dimension. Design education suffers from the idea that a larger scale is more complex than a smaller scale (closer to the daily experience of students), but it is not. 'Structure' in particular is not part of daily experience. To become acquainted with structure, the larger scale may be even more simple and appropriate. The resolution of understanding at a larger level of scale preliminarily neglects the complicating third dimension. Two-dimensional imaginations and problems are less complex compared to three- and four-dimensional ones. For educational purposes, it then may be wise to study the relationship between form and structure in the two dimensions that are dominant at a larger scale first. Moreover, the larger scale is the context of any spatial design object, a source and destination of its functions and intentions, and the source of its brief.

Structure in two dimensions

Structure in two dimensions at a larger scale is the separation from or the connection with (the exposure to, or resistance against) sun, plantation, energy, wind, noise, water, traffic, earth, cables and pipes, living nature, nature preservation, other people, environment in general and so on. You cannot study the impact on, or from, an object without knowing its content, its distribution in space, its form, exposure to or influence on these factors. You cannot calculate light and shadow, the behaviour of wind, water and so on without a preliminary design. Structure *supposes* a lay-out to study the possibilities of separations and connections. Structure thus can be taught best through asking questions about examples, or a student's preliminary design. A structure stabilising a *concentrated* form will be different from a structure stabilising a *dispersed* form, in regards to making them operational. A concentrated form may require more separations; a de-concentrated form may require more connections. Space separates passively, demanding expensive connections such as roads, rails, cables, pipes and the time for transport. But, concentration requires sophisticated solutions to combine separations and connections. Connections require separations perpendicular to the connection, resulting in elementary devices combining them (selectors, see *Fig. 8* on page 29), and separations require connections perpendicular to the separation. Different networks of connections may interfere (see *Fig. 104* on page 166). A student's preliminary design can be the basis for an exercise to study these effects in space, asking questions such as: "What did you do with sun, energy, plantation, wind, noise …" and so on. The students should dispose of computer simulations (see *Fig. 246* and *Fig. 247*)[a] to determine these effects in a given design directly, without complex mathematical effort, but with sufficient background information.[b] The calculations can be simulated appropriately in Excel with a little programming in VBA using sliders. Excel is available at many computers and the sliders enable one to choose an input *and* an output of the calculations simultaneously. Sliders enable the student to choose an output to find the right input. Such calculations are not intended to replace specialist advice. They enable designers to experiment, to ask the right questions in the language of specialists, and to make them less vulnerable in their company. The students become aware of the parameters (their names) involved in the calculations, of the behaviour of sun, wind, water and so on, in the designs made by themselves. Now you can ask them the same questions concerning how they will use the achieved knowledge in future designs.[c]

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[a] Sun .xls; Energy .xls; Wind .xls; Windvelocity(heigth) .zip; Wind behaviour of parcellations .xls; Sound and noise .xls; Water.xls; Trafficnetworks .xls; Earth .xls; Earthquakes .xls; Life .xls; Butterflies dispersion .xls; Human population .xls; Living .xls; Standard allottmens .exe; Environment .xls, downloadable from http://team.bk.tudelft.nl/ > Publications > 2009

b Jong(2009) *Sun wind water earth life living, legends for design* (Zoetermeer) lecture paper, downloadable from http://team.bk.tudelft.nl/ > Publications > 2009

[c] Examples of such exercises may be found at http://homepage.tudelft.nl/q7q71/ , http://homepage.tudelft.nl/1n01y/ , www.mmap.lt/viktorija , http://homepage.tudelft.nl/y71r1/.

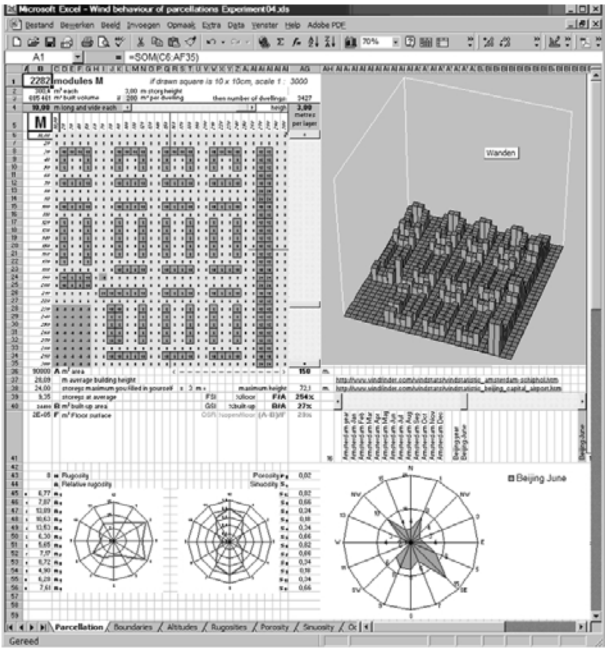

Fig. 246 R=100m Simulating wind

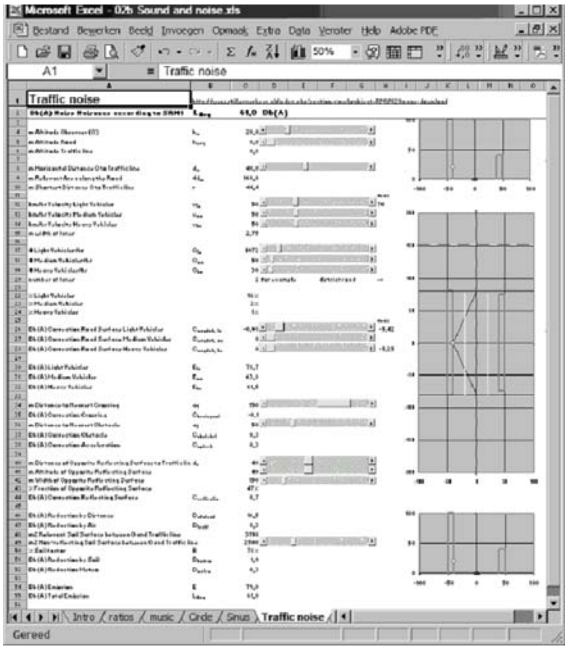

Fig. 247 R=30m Simulating noise

Structure in three dimensions

There are many dispersing effects to be prevented or compensated by separations and connections, such as the sprawl of cities, flood, and noise. Examples of passive *separation* by space in two dimensions can be used to introduce the thermodynamic principles of distribution, separation and entropy in three dimensions. The third (vertical) dimension subsequently adds the passively *connecting* effect of gravity, perpendicular to the horizontal plane. This plane already has shown the spatial *separation* and sprawl, probably compensated by high rise building, and *connected* to the ground by gravity. But, gravity is a different kind of connection (see *Fig. 71* on page 105). It does not connect different locations by dynamic flows; it connects piled up building materials by static force. It causes a vertical concentration of matter with an inclination for horizontal de-concentration demonstrated by the collapse of a building, the erosion of mountains, and the runoff of water. It introduces mechanics. The application of mechanics and thermodynamics at the smaller scales require a specialist's education. I will not elaborate on them further, because they are well developed.

Structure and operation, four dimensions

The fourth dimension (time) could be elaborated for education as 'difference of change'. Time is already silently supposed in the previous exercises as change by design, as flows at the Earth's surface, and as potential change by collapse. Different changes have enabled us in our first year to construct a third dimension by exercising parallax (see page 263).
But, this is not sufficient to understand differences in changes in the three-dimensional *operation* of a structure and its functional *performance*. Directing a flow in a pipe or through a gutter supposes a difference of change. Stable solid matter directs moving gases or fluids. But, even the solid matter of the pipe or the gutter changes in the long term, by breaking down. Their difference in change enables their current *operation*. If the water within a pipe freezes, then its operation will stagnate. The functional *performance* has its own time span, which interferes with the time span of the solid matter and the directed flows. If water needs increase over the years, the flow speed or quantity may become insufficient. A house is a stable device that enables the directed movements of people, furniture and commodities, and protects them against external changes. A town is a device that enables fast movements and dynamic processes next to stable structures to stay in rest. In the long term,

the elements of a town change at different paces. From ecology, we learn that sudden measures to rescue or restore an ecosystem may destroy it, by surpassing its own adaptation speed. *Fig. 226 The costs of increasing knowledge and reducing risks* on page 248 shows the problem of time-balance, as it appeared in the region of Adapazarı. The problem is known in management techniques, but as far as I know, not precisely elaborated in technology. Bio-mimicry may inspire technology by examples from living nature, but I do not know studies about grades of structural stability in nature, except some branches of ecology. Living tissues move with the processes they support, membranes even take part in these processes without losing their coherence. How to exercise the ability to imagine differences of change at different levels of scale? I do not know, but I suppose that they may be essential in future design education.

Typical functions

The use of an object of design is up to the users. A small part of this use is imagined and intended beforehand, and this may be represented in a brief. But, the actual use is only a part of a much wider 'function'. Any object will function at different levels of scale and in different time spans. You may use a theatre to see a play, but passengers outside the building recognise it as 'a theatre', and citizens know it as 'the theatre'. The longer the object will exist, the less predicable will be its final function in different periods, and at different levels of scale. You may refer to 'tacit functions' if they cannot be predicted, desired or even imagined beforehand. The designer's task is not to *determine* functions, but to make desirable, eventually tacit functions *possible,* and to avoid undesirable ones. As a functionalist designer, you will start with the brief, which is mainly represented in words and figures. The nouns in the brief are well-known categories (sets), referring to many examples. As a designer, you may study examples that have functioned similar to the client's intentions, but you cannot copy them.

Types, combinations of incomparable categories

If different examples show similar forms or structures, then you may have found a 'type'. A type is a combination of incomparable categories such as form and colour. An object cannot be more cubic than blue. A cubic, blue object thus is a type. Form, structure and function are also incomparable categories. An object cannot be more cubic than strong or stronger than useful. A half-round theatre thus is a type, a subset of at least two categories (sets). A type may get a name (amphitheatre), but it is a combination of well-known categories, an intersection of sets. A type is something in between a noun (referring to a category or set) and a name (referring to one particular unique object). To identify a unique object by words, requires adding as many suitable categories (expressed in adjectives or subordinate clauses) as necessary to indicate just one particular object. The study of types (typology) in design science may reduce the effort of functionalist designers to choose between an inconceivable amount of forms and structures that make the same function possible. A catalogue of previously built theatres may show different types of theatres with a similar form and structure being characterised as 'amphitheatres'. Choosing one of these types saves time, because it is proven to be possible. It makes the result recognisable: "Typically a theatre!". But, some questions may arise:

- Is it still possible (suitable) in the current context?
- Is the characterisation of examples the only one possible?
- Could you choose other groupings to typify them?
- Are there other examples that do not fit in any known type?
- Could you invent a new type, without any previous examples?

The function of a theatre is rather clear, but it may be combined with other functions such as a restaurant. And then, there are theatres where the meals are served while you are looking at the performance or during the breaks or even during the performance, producing different types. And, there are even more multi-functional devices such as a dwelling, a neighbourhood, a town (…the world). Summarising their possible functions gradually becomes a hopeless task. In such cases you may start the other way around by looking for forms that intuitively fit at the location, imagining different uses and functions amongst which surprisingly the required one is also included. I know two educational exercises that enable designers to cope with functions. The first exercise was invented by Hertzberger, a famous architect, but surprisingly, also an excellent teacher in architecture. Let me refer to his text[a] and summarise this educational method in four points only:

- Break off your clichés;
- Collect as many examples as possible;
- Put them in a different context;
- Combine, leave out, adapt.

It starts by an attempt to skip usual suppositions (clichés) to create space of thought. This enables looking without presupposed categories or types, the next step. But, I would advise to be a little bit selective avoiding mono-functional examples. If you take e.g. predominantly multi-functional objects such as dwellings, then you may leave out elements of form, structure and function to obtain a theatre, a school or a hospital. The strongest point, however, is the advice 'Put them in a different context'. It forces you to skip *and* add suppositions about the context. It makes you aware of its levels and layers.
The second exercise is invented by Tzonis and further developed by Guney, a popular Socratic teacher of TUDelft:

- Take an example that fascinates you;
- Analyse its Form;
- Analyse its Operation;
- Evaluate its Performance;
- Create an Operational structure to reach a better performance;
- Create a Form with this operation;
- Repeat.

This method is known as 'FOP' (Form-Operation-Performance).[b] 'FOP' is strongly based on morphological and structural analysis before evaluation and synthesis. Guney uses the methods of Ching[c], Clark and Pause[d], Steadman[e] and Tzonis[f] at an architectural scale. Burg and Stolk made an excellent overview of methods of analysis at urban scales.[g] Burg, however, experienced the limits of analysis before design in education. My experience is also, that you cannot teach design beginning by analysis. Many studios start by extensive analysis, and the students postpone designing until the last weeks. Asking them afterwards if the analysis had been useful in designing I never received a positive answer. Without making a preliminary design first, you do not know which analysis will be useful to make progress in designing.

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[a] Hertzberger(2002)*Creating space of thought* IN Jong;Voordt, *Ways to study architectural, urban and technical design*(Delft)DUP Science
[b] Moraes Zarzar;Guney(2008) *Understanding Meaningful Environments* (Amsterdam) IOSpress
[c] Ching(1975) *Architecture: form, space, and order* (Hoboken 2007) John Wiley & Sons Inc.
[d] Clark;Pause(1985) *Precedents in architecture* (Wokingham) Van Nostrand Reinhold
[e] Steadman(1989) *Architectural Morphology* (London) Pion Limited,207 Brondesbury Park
f Tzonis(1992) Huts Ships and Bottleracks Design by Analogy for Architects IN Cross;Dorst;Roozenburg, Research in design thinking (Delft) Faculty of Industrial Design Delft University of Technology the Netherlands Proceedings of a workshop meeting
[g] Burg;Stolk(2004) *Urban Analysis Guidebook. Typomorphology* (Delft) Technical University Delft, Faculty of Architecture, Department of Urbanism.

Design education in general

If the teachers of a university faculty do not know in some detail what other teachers teach, then their lectures, exercises and tests may become repetitive. The right sequence of what has to be learned by the students may be lost. I studied the contents of the Bachelors of my own faculty several times in the late nineties, a project that was assigned by the dean. Le Corbusier's Villa Savoye was tested 18 times. The required reading comprised 180 books. I gathered them all at my room physically. I questioned a random sample of students, and determined that most of these books were never read or even known by the students, because the test questions (covering only some pages of the required books) were gathered by the student union and generally known. Lecturers should write down what they want to tell themselves in published lecture papers before they are allowed to give a lecture. It is a necessary exercise for any teacher to obtain the right sequence, to avoid gaps, and to avoid overlaps with the other teachers. Referring to existing books should be additional, the obligation to buy them should be limited, and the pages relevant for the tests should be well-known. The faculty board should steer the content, not the titles of the subjects as they are presented by the teachers if it is not completely clear what they cover. This is particularly important in a design education that integrates many specialisations.

Different titles do not guarantee different contents

Publishing a new education programme causes a change of titles by the teachers for the same content. The titles are changed to fit in the programme. They may become vague or so general, that they never could be covered by one person. To keep an overview for the students and the board, and to become more precise about the content, the competence of any teacher should be summarised in approximately 50 key words per teacher instead of one title.[a] Duplicate key words should result in meetings between teachers for further differentiation and task division. Key words can be managed by a computer. Students may choose their specialisation based on key words, and even get specified marks for each of them, describing their competence more precisely if they are graduated. They will find their place in the job market in a more appropriate way. But the coordinating power of key words for the board is even more important. It provides them with a direction to develop the education content, determine its appropriate sequence in the educational program, and recognise duplicates and gaps. The gaps may indicate what kind of teachers are missing. The grouping of competencies and the task division between them in a faculty of Architecture as suggested by this thesis is based on three dimensions: the levels of scale in space and time, and the layers of design (see *Fig. 16* on page 52).

[a] A similar inquiry for professors of the faculty of Architecture TUDelft I once did in Jong(1997)*Hoogleraren Bouwkunde InTrefwoorden*(Delft)TUDBk

8.2 Empirical research

A sad history

In the eighties of the last century, the Faculty of Architecture at TU Delft contained three institutions for empirical research, according to three departments of the faculty: architecture, urbanism and housing. The department of Building Technology (closest to the faculties of civil engineering and industrial design) apparently did not require a separate research institution. The employees of the institutions were not designers, and they were often graduates from other universities. The research institutions were removed from the faculty in the nineties because the majority of the design chairs regarded their reports as useless for design. The housing institute survived as a successful separate university institute for government research. Their production had been impressive. For example, their reports on urbanism filled an entirely separate library apart from the main library of the faculty. This library disappeared within a week. I saw its reports and books piled up at the corridor of my building floor. Everybody could take whatever they wished, before they were removed. I rescued some of them for my own library, but this library was burned by the 2008 building fire. The design chairs took over the task of research, but they did not succeed in publishing a comparable quantity of research. They published more beautifully illustrated books than peer-reviewed journal articles. Their subject was predominantly history of architecture and urbanism. The recurring debate on methodology of design related study resulted in many conferences, and finally a book summarising nine types of study and research relevant for spatial design was developed.[a] This book has been used for five years in methodology education, but it has been hardly read by the employees. The department of Real Estate and Housing appeared to be the most successful in publishing. Their economic and managerial orientation on building production and function instead of design fit better with the typical empirical research methods. The pressure to publish in scientific journals and to increase the number of PhD's resulted in a return to typical empirical research. The department of Real Estate and Housing took over the methodology education, and now history is about to repeat itself(see *Fig. 248*).

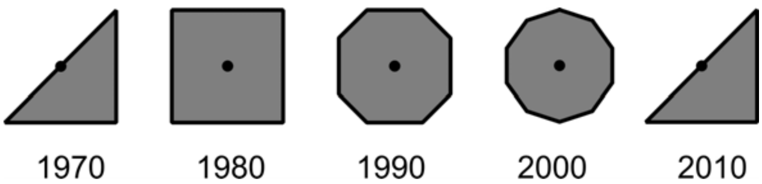

Fig. 248 Methodology of design study and research: the wheel cannot be re-invented frequently enough

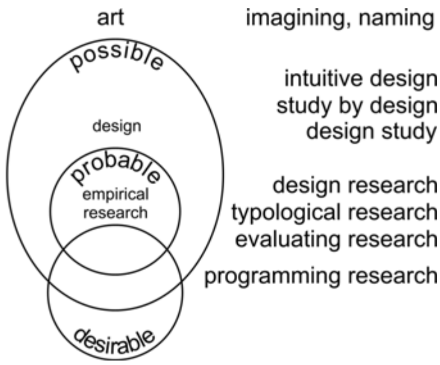

Fig. 249 Kinds of study relevant for design

Study and research relevant for spatial design

The specialised probabilities of empirical research seldom convince spatial designers that are searching for possibilities. Sector averages of many cases cannot be integrated as spatial layers in a special case. Separately generalised linear truths from different directions seldom fit a design project's spatial context, or its possible futures that have many dimensions. The parameters that are eventually able to produce a more context-sensitive deviation from the average specialist solution are often hidden in the linear inferences of specialists or their supporting computer programmes. Specialists may even not be aware of

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[a] Jong;Voordt(2002)*Ways to study and research urban, architectural and technical design*(Delft)DUP Science

them; they may assume that they are valid anywhere else or in the future. Moreover, a spatial context often requires many specialists supposing their own, sometimes even mutually contradicting, probabilities. Case studies can be made afterwards to indicate that the assumed parameters are not valid everywhere, but the context-sensitive conclusions of many case studies are even less useful in other contexts than the generalised averages. General conclusions may be useful for industrial designers, who are usually working on less context sensitive mass produced products with a smaller life-span, but not for unique objects in unique contexts. Moreover, design decisions do not concern the functions themselves. They concern the possible forms and structures, the physical *conditions* making the described function (and many other unpredictable and non-describable surprising functions, affordances) *possible*. Written reports cannot sufficiently engage the possibilities of form. The linear character of text is most appropriate to describe separate, one dimensional, probable, straight forward, and causally predictable *functions*. Text is not appropriate to describe two dimensional possible *forms* accomodating these functions. The sideward views of many possible functions, that are so obvious in a drawing, are lost in their causal line of reasoning in texts and calculations. It wrongly avoids logical paradoxes that are *allowed* in drawings. Empirical research has to cope with drawings to become relevant for design. According to Jong;Voordt (2002), *Fig. 249* shows the kinds of empirical research that are relevant for design. I will elaborate on them further along in the text.

Describing and naming

A 4D diversity and technique at different levels of scale considers numerous objects that can be described, typified, and categorised. Compared to the medical nomenclature (facing a similar 4D diversity and technique), the vocabulary of spatial design is very limited. Naming its objects in words may enable empirical science to cope with the diversity of spatial possibilities. For design operations, the *transformation* of an object into a different object is particularly important. Usual language is built up by sentences containing verbs between an actor x and a result y. A complete sentence thus has the form y(x), to be read as 'y as a function (working) of x'.

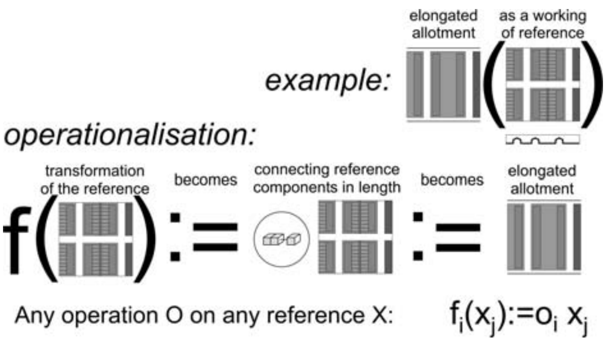

Fig. 250 Design operations

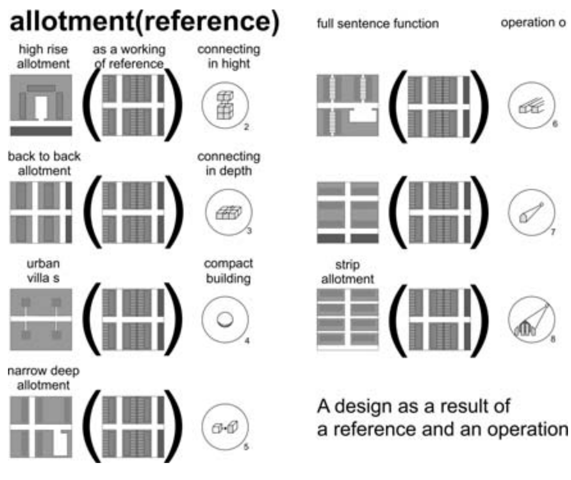

Fig. 251 Results of design operations

The brackets indicate the operation f(x) represented by the verb. In mathematical sentences this operation can be specified, e.g. as $f(x)=x^2$. But design operations concern images instead of numbers. You may replace x and y by images (see *Fig. 250*). *Fig. 251* demonstrates that many obvious design operations still do not have a name. But, if you draw the reference and the result as a complete sentence y(x), then the operation f(x) may be clear enough: 'design(reference)'. This simple notation as 'syntactic key word', however, is useful for many other, more abstract purposes, rather than naming design operations.[a]

[a] See Jong(2002) *Syntactic key words* (Delft) TUD Faculty of Architecture, downloadable from http://team.bk.tudelft.nl/Publications/2002/Syntactic%20keywords.htm

If I read villa(landscape) as 'A villa as it is influenced by (as a function of) a landscape', then it may be the shortest formula for a study proposal. Landscape(villa) would mean a different study proposal. The 'working' to be studied (the verb) is replaced by brackets ( ). A complete sentence y(x) does not have to *specify* its operation. That is an advantage, if you want to study or research an unknown operation. Research always aims to know 'how it works'; design study aims to know 'how it *can* work'. In both cases, the working is not known beforehand, and that is precisely what a complete sentence expresses. If the operation is still undetermined, then it can be interpreted as any operation:

- intuitive: f(x):= y associated with x;
- conditional: f(x):= y possible by x;
- set-theoretical: f(x):= y part of x, encloses x, without x ...;
- logical: f(x):= y if x, not x ...;
- mathematical: f(x):= x+x , x^2...;
- causal f(x):= y caused by x;
- temporal: f(x):= y preceded, followed by x;
- spatial(formal): f(x):= y near to, contiguous to, surrounded by x;
- structural: f(x):= y connected with x, separated from x;
- combinatorial: f(boards, nails):= a combination of boards and nails (e.g. a box).

A further advantage is, that this notation allows 'nesting' to become more precise. A verbal sentence cannot easily express more extended nested operations. For example, villa(landscape) elaborated in a 'nested' form produces different objects of study:

- villa(landscape(water-system))
- villa(landscape(water-system,history))
- villa(landscape(water-system(history)))
- villa(landscape((water-system,occupation)(history,spatial dispersion)))

If ')(' appears in the formula, then it may suggest a list of contents for your report:

1. water-system(history)
2. water-system(spatial dispersion)
3. occupation(history)
4. occupation(spatial dispersion)

The object of study does not have to be as concrete as a villa or a landscape.
It may be more abstract:

- urbanity(liveliness, choice)
- urbanity(liveliness, choice)(density, variety)
- form(function)
- function(form)

If the object of study contains opposite design methods such as 'form follows function' and 'function follows form', then you need the two last sentences both. If the sentence becomes to long to be understandable, then you can easily split up the sentence in more sentences. The object of study of this thesis could be summarised as:

- environment(diversity(design))
- design(intention(function(structure(form(content(scale,direction))))))

Combining them would not fit one rule. The index of this thesis (see page 322) uses short, complete sentences as syntactic key words, in order to allow you to find the precise subjects you are searching for more easily. It enables you to follow the range of words that successively define a concept, such as 'design', in this thesis. If you take x and y as environmental *variables* (see *Fig. 74* on page 114) then complete sentences may cover a diversity of *possibilities*. E.g.: Articulation$_{30m}$(Altitude$_{100km}$), or more precisely: Articulation$_{30m}$(horizontal … vertical)(Altitude$_{100km}$(lowland … highland)). It could produce a sequence of chapters:

1. horizontal articulation of building groups in lowlands
2. vertical articulation of building groups in lowlands
3. horizontal articulation of building groups in highlands
4. vertical articulation of building groups in highlands

But, a variable may concern many values in between two extremes. They are better represented as points in an x-y graph, than in a linear text, divided in chapters. And, *Fig. 74* on page 114 contains many related variables. Any relation between two variables, any combination of two of their values, still may have an infinite number of possibilities in regards to how they are dispersed in space. 'Form' thus is a second-order variable that is superimposed on the primary environmental variable. And, this thesis suggests that any form can be realised with different structures, producing a third-order variable of structure. Then, there are still fourth and fifth order variables of function and intention. All of these orders require design decisions. Could they be supported by empirical research? Naming design-relevant variables unveils at least the vast area of undiscovered design-relevant empirical research.

Design research and typology

Design research is studying examples (references, precedents) of different scales, their content, form, structure, function, and intention as inward operations and outward performances at different levels of scale, in different time spans, and from different (managerial, cultural, economic, technical, ecological and spatial) viewpoints. A design research programme should start distinguishing the design relevant variables according to space, time and layers as shown in *Fig. 16* on page 52:

(R=0.3m … 30km)(days…centuries)(layers).

According to the classification of that scheme, there would be at least 180 objects of study possible for each example. If you distribute these objects of study over the disciplines of *Fig. 16*, then there would be 180 disciplines involved, communicating in 180 specialist languages. And, there are many examples that should be studied before you may, or may not, arrive at a typology (see page 270) that is useful for any design. It is obvious, that such an endeavour is a hopeless task. But, it puts any case study in perspective. It makes the object of study nameable and retrievable by key words, representing a set of limited variables. The case studies I know could be characterised that way:

- Example(space, culture)(centuries)(R=30m)
- Example(space, technology, culture)(centuries)(R=300m)
- Example(space, technology, economy)(months)(R=1m)

This characterisation, however, only concerns the variables involved, and the content. But, what about the form, the structure, the function and intention? For empirical research, they are implicitly included as variables in the physical and social layers. In this thesis, they are made explicit for design, which can be considered the art of improbable possibilities. For empirical research, only existent examples are relevant, not the possibilities to change them otherwise than proven in other existent examples. The existent form may play a role primarily in space (the actual form) and culture (the perception of form); the existent structure may play a role in ecology and technology. The primary object of empirical research is the existing object and how it works in the layers of an existent context, not the making of an object that still does not exist (see *Fig. 50* on page 93).

Evaluative research

Evaluative research is a kind of design research that explicitly takes the mode of desirability into account (see *Fig. 249* on page 273). It occurs frequently in nearly any design process of an object in progress, or after realisation, in order to prepare programming studies for similar projects. Any specialist evaluating a drawing as a manager, a client, an economist, a technician or an ecologist, evaluates if the impacts are desirable in her or his domain (see *Fig. 234* on page 256). Any specialisation has its own methods. This thesis does not discredit them as truth-finding. It puts them in a perspective of possibility-finding. This may have some consequences as already has been explained in Chapter 7 in pages 245 and onwards.[a]

Programming research

Making a brief surpasses the boundary of probability, by studying non-probable desirable futures (see *Fig. 249* on page 273) within the limits of what is supposed to be possible (see also *Fig. 2* on page 17). It translates intentions into functions, which are mainly based on a limited imagination of existing types and examples. Programming research is inclined to extrapolate probabilities into desired possibilities. But, if the client is a less experienced institution or person, then the brief may be made in interaction with a designer. The designer will introduce possibilities that are beyond the client's existing desires. In that case, you could name this kind of research 'programming *study*'. If many stakeholders and specialists formulate their desires, then 'optimising research' is part of the study. Both are elaborated on often enough, so it is not needed to elaborate further on them in this text.

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[a] See also the Chapter 'Evaluating' in Jong;Voordt(2002) *Ways to study urban, architectural and technical design* (Delft) DUP-Science http://team.bk.tudelft.nl/Publications/2002/Jong(2002)WaysToStudy(Delft).pdf

8.3 Design related studies

Technical study

Technical study in a design environment goes beyond ‘construction’. It has consequences for more encompassing design study. It is a means-directed exploration of mere technical *possibilities*. *Desirable* futures play a lesser role. Technical inventions have changed people’s desires, their economic demand, their culture, their priorities. Existing desires are based on what people know, and what they *suppose* to be possible. A good example is the invention of how to use computerised fabrication in order to produce curved glass surfaces that fit in curved façades.[a] Nobody wanted them before their possibility had been proven and the suppositions about their price had been falsified. Once this had happened, it became a hype in order to fulfill hidden desires of identity and representation through surprising buildings. Short term valorisation may hamper technical study. Its risks may by high, but trusting the limited imagination of the majority of people leads to a technological stand-still. Technical study has its value, even if the result may be, that a construction is not possible or too expensive in the given circumstances. Reporting the failure of an idea in detail may be not very popular, but it is essential in the advancement of technology. I have learned more from failures in construction than from the many advices how to construct ‘properly’ according to the existing experience. The physical technical experiment is a crucial part of technical study. Its sup-posed operation is the ‘hypo-thesis’ to be tested by empirical research. The method of empirical research may be rather strict, but the choice of a hypothesis to be tested is fundamentally free. If the hypothesis is not free, then you may realise the consequences if you remind the history of Copernicus and Galilei. If the choice of an *experiment* is not free, then you will miss the possibilities that may be opened up by the experiment. In technical study, the hypothesis requires the greatest effort. The testing is the minor part of the study. The hypothesis contains an often expensive operational structure to be built first, *before* you can test its operation in an empirical way. Its eventual failure must be reported in detail before you may find (often minor) successful improvements. The role of experiments and thought-experiments will be elaborated further in the paragraphs below.

Design study

Design study is the usual activity of design bureaus with projects in determined contexts (see *Fig. 50* on page 93). It is a possibility-search that is limited by the many probabilities and desires stemming from this context, its specialists and stakeholders. But, the imagination of these probabilities and desires are often bound to a shorter term than the object of design will exist. The designer may increase the flexibility of imagination of the stakeholders and specialists involved, by showing possibilities and discussing the future context (see 7.4 on page 253). Design study does not solve single problems. It must cope with a field of related problems and aims stemming from more than one specialist or stakeholder. The role of experiments in design study is limited. The scale models made to imaginate a 3D design proposal do not include people. As it is the case in the humanities, you cannot experiment with people bringing them into the extreme situations as technological study may do with dead materials. Experiments of design study beforehand, are mainly thought-experiments *supposing* human behaviour in the unprecedented context proposed. The final experiment is the realisation of the design. Its eventual failure is seldom an object of evaluative research. It may harm reputations and it may decrease the value of the object. The owner will object its eventually negative conclusions in order to provide for its yield. The lacking support for evaluative research reduces the progress in design study to the application of technical advancements. It may be the task of universities. As Hertzberger advised his students to extend their imagination through putting existing examples in a different context (see page 271), taking existing *contexts* not too serious adds new possibilities for design study. This is meant by ‘study by design’.

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[a] Vollers(2001) *Twist & Built creating nonorthogonal architecture* (Rotterdam) 010 Publishers

Study by design

From a viewpoint of empirical research, study without a determined object and context (see *Fig. 50* on page 93) is bizarre. It cannot formulate a clear problem or aim, and its outcome is uncertain. It may come closest to visual Art. If it is Art's task to explore what is *imaginable*, then the task of study by design is to explore what is *possible* within that area of the imaginable. For example, Escher's work is imaginable, but not always possible. The field of study by design is consequently smaller than that of Art. It studies possibilities by means of executable design. Study by design, then, is not primarily aim-directed, but means-directed. This thesis studies these means of design in order to extend them into the boundaries of what is imaginably possible. The means of design distinguished in this thesis are its orders of diversity: content, form and structure at different levels of scale, in different contexts. Technical design is restricted to structure, but design study does not have to start there. Design study has not one method in the sense of one particular sequence to be followed, but it can be done systematically. It can choose to experiment with different forms that are possible with one particular structure, but it can also start with one particular form to explore which structures are possible to realise that form. It can be cyclic, adapting the structure in order to reach even more improbable forms and then adapt these forms to reach even more improbable structures. It that sense, it serves design studies without the burden of a particular context. Form and structure are well-known means of design, but they suppose a third order: content, the values that are taking form and structure, the legend units in a drawing. They are often forgotten through the supposition that they are limited, but they are not. They are neglected with the consequence that they have become limited by tradition, a lack of awareness of their possibility to diversify environments. Technical study did not forget content, because any construction requires well-defined materials. The great advancements of technology even started often through emperiments with matierials. Materials in the sense of content that can take form and structure, do not only contain wood, brick, concrete, steel or glass. Its study goes beyond building materials. It encompasses any chemical substance applicable at different levels of scale. In fine mechanics diamond and gold are studied to determine which forms they can take, which operations are possible at the lowest levels of scale, even regardless which function these operations may possibly perform. Experiments forcing materials in extreme and very improbable conditions are the core of this kind of study. Content, however, is not only limited by chemical substances. For example electricity is also a kind of content that may take different forms, that can be forced in different conditions and structures by experiments. It has been discovered in the 18th century. Many experiments have been done without any prospect on substantial application, before the applications we know now, had been realised. This thesis started with an inventory of contents that can take form at larger levels of scale than electrons and molecules. If it succeeded to extend the awareness of the values you can imagine in the diversity of environments (the legend units you can use in your drawings at different levels of scale), then there is a long road of experiments ahead. They can be done without any prospect on substantial application, but it would be improbable if there would never appear any application that may change the world. The ordinal arrangement of values in variables may be a tradition that is typical for empirical science, but in the two or three dimensions of a drawing, different values (legend units) may be exposed to each other in a combinatoric explosion of arragements opening up new possibilities. It is the task of study by design to explore these possibilities systematically through thought experiments. Take a variable and distinguish as much values you can. Look which dispersions in space (forms) are possible for every value as a legend unit, look how you can combine them with other values of other variables, how you can stabilise the form by some structure, still regardless of the functions in can perform, the intentions it can fulfill. This context may hamper the possibilities of design. Designers with a sufficient luggage of possible contents, forms and structures may be ready to accept assignments for design study.

9 Conclusion

A linear language cannot cover space, its diversity or possibilities

Words collect earlier experiences as sets, neglecting the differences between their elements. They reduce reality into a 'linguistic average'. Sentences, then, connect averaged nouns with averaged operators, (i.e. verbs or signs referring to generalised actions) in a strict sequence. A sentence cannot be read backward, not to mention sideways, unlike a drawing. This thesis tends to be an affirmative answer to Jackson's question: 'Is it possible that we … are unconscious victims of our language when we attempt to interpret architecture?'.[a] Every brick, beam or plate is a part of many sequences, in many directions. A linear language cannot tell the many possible stories of every element. It reduces reality into one 'linguistic direction'. The language of speaking, writing and calculating is primarily time-based. It reconstructs a reality through imaginary operations. Describing space in a line of words in one direction (i.e. the arrow of time), however, cannot be more than a travel report that neglects the side roads, and the more remote context. Moreover, it substantially reduces the spatial diversity (as it has appeared to your senses) into commonly generalised words. Crossing lines may indicate points, and their mutual distance is represented in words. But, Cartesian points and distances cannot describe the experience or use of the space. In other words, they even substantially reduce the *awareness* of a possible diversity. A thesis is assumed to be expressed primarily in words, propositions or calculations, but this thesis meets their limits.

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[a] Jackson(1994) *A Sense of place, a sense of time* (London) Yale University Press p32

Poetic associations cross the line, but design covers many more directions

Using words as descriptions requires to assume that these descriptions will lead the audience or the reader to recall similar experiences, but you cannot be sure that they will do so. Words act in a 'linguistic game', a context that hides many suppositions (i.e. a '(sub)culture': a set of shared suppositions enabling communication). The linguistic game of poetry may evoke different imaginations by unexpected combinations of words. It may reset your imagination or extend it into different directions, but it will still not cover the possibilities of space a designer must balance. It allows to re-arrange the sequences of reality by imagination, but it is still bound to the sequence of words in a sentence. You may fill the words of a poet with the experiences you may recall yourself: smells, sounds, emotions and places you vaguely remember, combining them in unexpected sequences, but future-oriented spatial design must be more. Poetry is closely related to the other time-based art of music, evoking the same kind of recollections. Their combination in a song, however, seldom reaches a sublime unity of sound and story on their own. The appearance of video clips adds a spatial dimension covering the eventual poorness of one of both mixed in a synaesthetic experience as operas and musicals did before. Dance then adds a substantial and fascinating motoric sensation in order to experience touch and space. It puts story and sound into perspective. This is the spatial perspective of closeness and distance supposed in any sequence.

The direction of linear reasoning cannot be determined by linear reasoning

Even the *choice* of the direction or route, its beginning and its end, as applied in this thesis, cannot be justified in sentences with only one direction. A picture or a map may help, but it also does not fully show the context and tacit[a] (but not less valid) arguments of such a choice. You cannot describe all the side roads that you passed by in words, except by referring to footnotes, other reports or chapters. If you would describe all side roads this way, your listeners or readers would lose the 'thread' of your inference. They would reproach you as 'deviating from the subject'. They like the connecting word 'thus' more than the separating 'but'. Your report, thus, may result at most in a tree-like structure, with one stem, and separate chapters describing some branches. In the common language-games of policy, management, empirical science and the humanities, a line-wise reasoning is useful and broadly accepted. Spatial design and technology, however, require more dimensions than the one provided by common linear language. The pictures of this thesis are thus not clarifying the text. Rather, the text clarifies the pictures, by taking seemingly arbitrarily chosen routes in their still two-dimensional space. The references in the text mainly refer to figure numbers instead of chapters, sections or paragraphs. This is not accidental.

Space includes the gaps between the linguistic lines of reasoning

This thesis, in regards to diversifying environments through design, cannot avoid taking on a tree-like structure that is full of gaps, which are left to be filled by the imagination of the reader. It attempts to grasp the sky by a stem (i.e. the describable diversity of environments) branching into variables. Variables are words, each assume a sequence-bound line of values. These lines crisscross the air, without any possibility to offer a complete coverage of the sky, but they have the capacity of further branching through space. The reader must jump from one line into the other, in order to experience the gaps and to discover the *possibilities* of space. The conceptual tree and its branches can be cut into pieces, in order to obtain a different form and structure, and to fulfil a different function and intention. The values of the variables can obtain different sequences in space, compared to the sequence you needed to imagine them in their simple linguistic line-form. A second branching (i.e. a second order of diversity) opens up another universe of possibilities for every single variable or value: the inconceivable possibilities of form. The kind of linear logic reasoning (valid for relating sequenced variables) must be left behind. This is not an easy transition of

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[a] Polanyi(1966) *The tacit dimension* (New York) Doubleday

reasoning. The transfer into the second order of 'branching the branches' requires a different kind of thinking in forms, allowing contradictions that are perpendicular to the primary line of reasoning.[a] A bridge is open *and* closed. A boundary, a road or a pipe line connects *and* separates, depending on the tacit direction of reasoning. Which kind of reason can cope with such contradictions? Does every branching grafted on branches of a previous order have something in common? Is 'form' the final order of branching? This thesis cannot answer these questions in a sense of 'truth'. It only shows some 'how'-answers, proving their 'possibility'. Focusing on possibility raised the many methodological issues addressed in Chapter 1 and 2. Some possibilities to overcome these barriers, however, are demonstrated in Chapters 3 - 8. Until now, this Chapter has drawn some conclusions concerning these barriers. The rest, thus, primarily concerns chapters 3 - 8.

Superimposing 'form' multiplies the possibilities of 'content'

Diversifying an environment primarily assumes a possible *content* of its diversity. This content can be described in the one dimension of common language, by naming variables and their sequenced values. Interpolating and extrapolating these variables can extend the observed diversity into new, possible values. These values can be used as legend units in a drawing, but there, they may lose their original position in the verbal or mathematical sequence of the variable. This increases the number of possible sequences in space. The values of different variables will show different sequences in different directions. This combinatoric explosion of potential forms is superimposed on the potential content. The dispersion of a legend unit in space (i.e. its 'form'), and the possible diversity of this second order, cannot be described fully in common linear language. It requires at least two dimensions. Form can be imagined without a determined content, but it tacitly supposes *some* content (e.g. the black and white of a sketch). Describing structure, however, requires imagining simultaneously at least three dimensions, function 4D, and intention even 5D. Function adds time as a necessary explicit dimension to the three dimensions of structure, and intention subsequently adds a dimension of desire. An intention, however, concerns *some* function to be desired, and a function tacitly implies *some* structure within which it can function. A structure (in this thesis defined as a 'set of connections and separations') subsequently requires *some* dispersion in space of *what* is connected or separated (i.e. *some* content), even if this 'form' is still topologically variable.

Super-position supposes sub-position in a conditional sequence

Thus, the successively distinguished and superimposed diversities of content, form, structure, function and intention also obtain a sequence that is represented in the chapters of this thesis, but it is not a causal sequence of operations. It is a non-logical 'conditional' sequence, producing possibilities instead of probabilities. The variation of some variable does not make the dispersion of its values in space *probable*, it makes still different forms *possible*. It is not a preferred sequence in a design process, either. A design process may begin anywhere, imagining an intention, a function, a structure, a form or a kind of content, but once you have determined one, the other conditions must be determined in order to realise it in this sequence, proving its possibility.

The meaning of words can change by scale

Text-based literature can draw unreliable conclusions if the scales within which they are valid are not explicit. The content (i.e. the 'material', the set of variables describing the design-relevant possible diversity of environments) is bound to scale. Many variables have an upper and lower limit of resolution (this thesis refers to them as 'frame' and 'grain'). Changing the resolution may substantially change the meaning of the variable. For example, the environmental variable 'light', varying in a radius of 1 metre, distinguishes environments

[a] This 'thinking sideward' is perhaps related to the 'lateral thinking' intended by Bono(1967) *The Use of Lateral Thinking* (London) Jonathan Cape or Marcuse(1964) *One Dimensional Man - Studies in the Ideology of Advanced Industrial Society* (Boston) Beacon Press

differently from the way it does in a radius of 100km. The question of how to determine the limits of scale, where one meaning changes into a substantially different meaning, has been answered in my first thesis[a]. But, this answer was given a better foundation in this thesis. *Fig. 7* on page 21 and *Fig. 17* on page 52 show their foundation: the scale paradox and the concept of a 'nominal radius'. *Fig. 7* proves that already a factor three difference in a 2D scope can cause opposite conclusions about 'difference' (scale paradox). This suggests a logarithmic sequence of orders of size, in order to determine where a variable may obtain a different meaning, but it still does not determine the limits themselves. For many practical reasons, (the size of built-up areas[b], the mesh-width of networks[c], measures easy to remember) the semi-logarithmic range {… 3, 10, 30m …) has been applied in this thesis. These measures, however, are still too precise to distinguish environments of different 'orders of size'. *Fig. 17* thus shows in which range they can be interpreted, if you give them a broader 'nominal' meaning. A *nominal* measure of '10m' ,then, can be interpreted as any size between 3 and 30m. This flexibility may cause overlaps, but in this thesis it has appeared useful to distinguish orders of size of content, form, structure, function and even intention. In order to make these orders of size independent from directions, I chose the *radius* of the circular frame R and the grain r, in order to indicate the *nominal* size and resolution r/R. You now can use a nominal radius R to indicate an order of size, and add r to determine the intended resolution r/R. A sketch, then, has a resolution r/R of 1/10, a drawing of 1/100 and a blueprint of 1/1000, with very broad margins. Any picture between r/R = 0,3/300 and r/R = 3/30 may be named a 'drawing'.

The concept of 'form' as 'distribution in space' has nameable extremes

In this thesis, the concept of 'form' is separated from suppositions of 'meaning'[d] and coherence, or even adjacency, between elements. 'Meaning' is assumed to be a possible *function* of a form for humans, but the form itself is limited to 'distribution (of some content) in space'. Coherence is assumed to be the effect of a possible *structure* of form. A set of connections and separations stabilise the form, giving it coherence. The same form may have different structures, (i.e. a third order of branching in the thesis) and the same structure may have different functions (i.e. a fourth order of branching). Even the adjacency of the elements that give the 'form' a clear boundary (i.e. 'shape') is not necessary to ex*plain* 'form'. Without a supposition of adjacency, you are able to think about the 'form' of some dispersed content (e.g. trees, parking lots, buildings). The 'form' of a city depends on the distribution of built-up area, but between the buildings, there are still many public and private open spaces that represent other values than 'built-up'. If the city-outskirts gradually turn from 'built-up' area into open rural land, the boundary cannot be unambiguously determined. If you skip the connotation of boundaries and adjacency of its content, then any separate value can obtain a describable form between extremes of total accumulation and total dispersion, at any level of scale. This seems to open up the possibility to describe 'form' as a variable between these extremes. A line, then, would be the total accumulation in one direction, and total dispersion perpendicular to this direction. Total accumulation can be described as the absolute value or zero-point from where the deviations can be measured. This, however, does not solve the question of how to measure deviations from these extremes (e.g. local thickenings of the line or accidental surfaces outside the line) in different directions. This thesis did not succeed to cover the possibilities of form in a systematic way. The number of forms between the univocal extremes shows a combinatoric explosion of possibilities, which cannot be solved by two or three extremely different (perpendicular)

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[a] Jong(1978) *Milieudifferentiatie* (Den Haag) RPD TUD

[b] For example, Blaeu(1652) *Toonneel der Steden* (Amsterdam) Blaeu, shows mainly cities R=300m, a size now known as 'neigbourhood'.

[c] Nes;Zijpp(2000) *Scale-factor 3 for hierarchical road networks a natural phenomenon?* (Delft) Trail Research school

[d] Forty(2000) *Words and Buildings A Vocabulary of Modern Architecture* (London) Thames & Hudson p149 writes: "There is in 'form' an inherent ambiguity between its meaning, shape' on the one hand, and on the other 'idea' or 'essence': one describes the property of things as they are known to the senses, the other as they are known to the mind." The last connotation of a platonic ειδοσ (appearance *and* idea) is thus rejected in this thesis.

directions (Cartesian coordinates). A reduction of the inconceivable number of possible forms, however, can be reached by distinguishing between different *resolutions* or levels of *scale*.

Different resolutions produce different forms

If 'form' is a human construction derived from what you can observe through your senses, then it is limited by their resolution. The form of a building is different from the form of a city. Changing the frame of a photograph changes the forms or compositions you perceive. The often invisible structures that stabilise these forms at different levels of scale are different, and for every particular form, there are still many structural and functional alternatives. Thus, studying form at different levels of scale separately simplifies the study of form and its consequences substantially. Forms at different levels of scale, however, are mutually related. The topography and geomorphology of a land limits the remaining possibilities of urban and agricultural forms. It seems reasonable to assume that the larger form mainly sets the boundary conditions for the smaller form, but there are many examples of smaller forms determining larger forms (e.g. by repetition, the growth of crystals, a design composition). Therefore, this thesis does not suppose a conditional sequence of scales. Looking at the diversity of forms from $R = 10^{-18}$ until $R = 10^{26}$m, the greatest diversity seems to appear between $R = 10^{-6}$ and $R = 10^{6}$m.[a] The diversity of forms at the lower scales increases from physics into chemistry, and from chemistry into biology. The diversity of forms at the larger scales, including the diversity of human artefacts, does not measure up to the inconceivable diversity of organic forms, until 1m. At the even larger scales, the diversity of forms decreases. The development of the organic form within and outside the living cell ($R = 3$ - 30μm) is increasingly limited by structures that develop as stabilising parts of the form. Separations and connections increasingly limit the degrees of freedom of its elements (their entropy). In the human design of artefacts, forms can be imagined (not realised) without structure. This enables the imagining of alternatives of structure that can stabilise the same form. In 'evolutionary design', however, the form results from gradually adding structure (imagined as 'rules' limiting movement and change).

The most general structure is a polarity between 'closed' and 'open'

A connection limits movements into one direction, through separation into other directions (see Fig. *Fig. 130* and *Fig. 131* on page 185). You cannot connect your lamp with the electricity grid without isolating the cables. Separation is a necessary condition for connection. In other words, connection *supposes* separation, not the other way around. Space operates as a primary kind of separation. Its degree of separation can be expressed as distance. A zero-distance between two objects may be called 'connection', but it limits the movement of one of the objects to only one direction. The other directions are still 'open' for movement, but other objects at some distance into the other directions still limit the freedom of movement. Therefore, following the inference above, instead of referring to 'openness', you may better refer to a 'low degree of seclusion'. The development of organic form very often shows successive degrees of seclusion. If they are ordered in a sequence from closed to open, there is a structural polarity between relatively 'closed' and 'open'. This polarity can be recognised in the development of organs, organisms and organisations.[b] It probably allows different degrees of freedom from regulation into coincidence and entropy. This polarity also can be recognised in utensils, furniture, buildings and cities. This thesis proves the possibility of the application of polarity at any design-relevant level of scale. Studying the possibilities of subsequent levels of scale suggests an alternating appearance of motoric and sensoric polarities at every factor 3 scale difference, according to the scale paradox.

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[a] See Boeke(1957) *Cosmic View* (New York) John Day, and Morrison;Morrison; Eames;Eames(1982) *The powers of ten* (New York) Scientific American Books, Inc.

[b] Sinnott(1963) *The problem of organic form* (New Haven) Yale University Press

Spatial functions cannot be designed

A designer may take a list of desired functions (e.g. a brief) as a starting point for design, but fulfilling these functions is up to the users after the design is realised. As a designer, you cannot do more than afford *possibilities* of use. You do not design a house to *cause* a predictable household, you shape *conditions* to make many households *possible*. You must propose a content, a form and a structure first, before they can be evaluated on the *probable* functioning of your design by stakeholders and specialists (i.e. evaluating research). The larger the object of design, the longer it may be used, the more people of next generations will use it, the less certain will be its uses and the more adaptable or multi-functional it must be. Smaller mobile objects of industrial design, with a shorter period of expected use, can be designed for specific functions that fulfil the desires of current generations in many contexts. These desires can be predicted by empirical research, and fulfilled by mass-production. But, larger location-bound objects with a longer time-span of existence have different functions in a *specific* context. What *can* be studied concerning their functions *in general* (i.e. at average) has diminishing returns, because every environment is unique in its potential. What *can* be generalised for any environment is already generalised many times by empirical research.[a] What remains to be studied are *specific* cases, their relevant spatial, ecological, technical, economic, cultural and managerial *layers* of context, at different *levels* of scale in space and time, represented by different stakeholders with different expectations. Their expectations and desires, affected by an object still to be designed, stem from their *position* in different layers and levels. Before summarising their desires, a designer may first locate their positions, and make an inventory of *expectations* from each position. This may produce more generally expected futures in a determined time span. These *probable* futures determine what is *not* desirable (i.e. the 'problem *field*'). This strategy avoids thinking in a linear linguistic average of desired functions, neglecting the broader possibilities of design. It provides a *field* of aims.

Mono-functional environments postpone satisfaction

A spatial design is thus functionally layered, and more or less multi-functional. The traditional home or autarkic farm is the most multi-functional R = 30m environment from which the history of specialisation separated mono-functions (e.g. work, education, care, religion, recreation) into a larger urban area.[b] It still enables a spontaneous choice of immediately satisfying (solo-functional) actions. It compensates the forced sequence of not immediately satisfying (inter-functional) actions of a programmed working week outside, where the agenda rules. The necessary sequence of inter-functional actions to reach a final satisfaction has been extended by involvement in the aims of your employer or client. In the course of human evolution, task division has increased the number of inter-functional actions in mono-functional environments, at the cost of solo-functional actions in multi-functional environments. Urban design may develop more multi-functionality R = {100, 300 and 1000m} in order to restore more solo-functional actions.[c]

Any object with a useful interior has at least two functions

In this thesis, and thus tacitly in the previous paragraph, the concept of 'function' is limited to functions for (wo)man and society. Even with this restriction, however, the concept of function is ambiguous. A house may have an outward function for the city (and its inhabitants), but it also has a different inward function for its occupants. The difference between inward and outward function is often neglected. It is based on two opposite directions of view, sometimes leading to contradictions. For example, a house *affords* space for its occupants, but it *takes* space from the city. The sensory perception of a building outwards and inwards is substantially different. If you diversify the outward function into more directions, then there are even more functions to be distinguished. Your house may

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[a] For example Neufert(2001) *Architects' Data* (Malden, MA.) Blackwell
[b] Mayntz(1955) *Die moderne Familie* (Stuttgart) Ferdinand Enke Verlag
[c] Hoog(2012) De Hollandse Metropool, ontwerpen aan de kwaliteit van interactiemilieus (Bussum) Toth

have different functions for your right, left, and rear neighbour, and for the street. The same may apply for the inward functions. A sentence, such as 'This house has a positive effect upon its neighbourhood', hides many functions in the 'linguistic average' of its statement. Moreover, this effect or function should be distinguished further, into levels of scale and layers of context. Do you mean a spatial, ecological, technical, economic, cultural or managerial effect (function), or an overall effect with an implicit evaluation and balancing of its components? Does it apply for the direct neighbourhood R = 100m, or for a wider neighbourhood R = 1000m?

A design affords more functions than ever can be summarised in a brief

Any list of desired functions for a spatial design or brief falls short of what humans need. In its time span of existence, a realised spatial design may obtain numerous unexpected 'tacit functions'. Desires will change at different levels of scale, and in different layers of context. A periodic change of politics will alternate between priorities for the higher and the lower levels of scale. New stakeholders will appear with new spatial, ecological, technical, economic, cultural or managerial priorities or innovations. A natural response of design to these uncertainties is providing diversity at different levels of scale in the spatial layer, inspired by the diversity in the other layers of context. The uncertainties concern the current and future intentions that are assumed to be directed by free will. This possible variety beyond the brief justifies a backward effect on the design, and on the imagination of the designer. (S)he must extend the imagination of the current stakeholders and specialists, through design from their probable and currently desirable futures into *possible* futures. The aim is to realise a design that *extends* human possibilities, instead of *limiting* them through mono-functionality. The diversity of intentions is not merely a barrier to finding a clear linear route from the problem to the aim. But, it is also an opportunity and a challenge to diversify environments in different directions, solving *many* problems, and fulfilling *many* aims in space. Space enables many routes instead of one.

Space allows realisation of contradictory intentions

The great advantage of space is its capability to allow contradictions to be next to each other (e.g. dark *and* light, wet *and* dry, cold *and* warm). Freedom to choose between them primarily requires separations. *Separations* maintain *differences*, enabling selective connections (e.g. windows, staircases, doors, roads, lines of vision and motion), which can be referred to as 'selectors'. Selectors based on separating environments have made life possible, from its smallest until its largest scale. In the living cell, membranes create separate environments for different chemical processes in order to regulate their sequence. Cells are separated from the outside world by a different membrane, and so are organs, organisms, organisations and landscapes. They are separated from the rest, in order to obtain their own identity. Non-selective *connections* produce *equality* rather than difference. Space primarily separates, but it allows connection at the cost of time. Contemporary society emphasises connection and exchange. It neglects the necessary differences, in order to make exchanges valuable. Exchanging the same objects has no use. Separation sounds negative, but separations are necessary to enable a valuable, selective connection. You are, however, educated to think in connections. Your linear language emphasises the *connections* in an argument, but without sufficient *difference* between the words, the argument becomes meaningless.

Knowledge is a set of tested suppositions

Suppositions[a] may give direction to your actions, but they may also hamper them. The core of education, study and research is to transfer and to create more useful suppositions than those that are usually taken as a basis for action. People act with different and mainly unconscious suppositions. If you build your argument upon tacit suppositions[b] that you do not share with your audience, then this causes failing communication and education. Therefore, any inference or course requires an awareness of suppositions in order to obtain the right sequence. Any spoken or written language contains an extended set of common suppositions. Every spoken or written word implies the dubious supposition that it refers to similar past experiences. Their similarities are named in words, recalling a constructed 'average experience'. Without any memory of experiences, you cannot name their supposed similarities in words, and their connection in sentences remains meaningless. The supposition that there are similarities in different experiences is dubious, *because* they are different. The similarities have proven to be useful in giving direction to one's actions in similar situations, but the situation is never exactly the same. The direction of human action is linear and primarily time-based. The necessity to communicate *actions* may have been the prehistoric origin of language. Words are the shadows of action.[c] Any action can be described by a verb referring to similar actions in the past. It connects the initiator (the causing *subject*) with its effect (the affected *object*) in a complete sentence. The situation of action, however, has more dimensions.

Design education, study and research goes beyond the limits of language

Space is experienced visually primarily via a two-dimensional impression on your retina.[d] The third dimension must be constructed (i.e. imagined) by movements that are perpendicular to this planar scene.[e] The visual impression is continuously replaced in a flow of parallel images, fading in a series of memories connected through your own actions of movement. A spoken or written linear language is well suited to describe these *actions*. The *situations* with at least two dimensions and a spatially constructed third one, however, must be averaged to be named in generalising words (e.g. 'at home', 'in my office' or 'in the forest') in order to fit into a linear sentence. These situational indications are in addition to the sequence of your sentence describing what you have experienced through the actions of

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[a] 'Supposition' stems from Latin: sub-positum (placed underneath). It is exactly the same word as Greek υπο−θεσισ (hypo-thesis). In this thesis anywhere possible the word 'knowledge' is avoided, because it assumes a 'truth-value'; it does not allow a 'possibility value'. Instead, 'knowledge' is replaced by 'set of tested suppositions' as it is always open for falsification and improvement. The 'truth' value of a statement is thus only temporarily. There is fundamentally no 'knowledge' or 'truth value' concerning *possible* futures. Instead, there is a 'possibility' value. From this viewpoint, the term 'design knowledge' is misleading, but 'design suppositions' can be applied to possible futures indeed. Suppositions are imagined reconstructions or simulations of an assumed reality 'standing outside' of you (Latin ex-statum, recognisable as ex-sistent or existent). The 'possibility' of a supposition can be tested by realisation, a series of actions based on these simulations. Your actions follow a simulation, directing your muscles by a motoric nerveous system. In this sense, suppositions give direction to your actions.

[b] Suppositions suppose other suppositions (e.g. 'Suppose p, then q is true or q is possible'). The search for suppositions 'placed underneath' a given supposition, however, does not primarily require a logical or causal 'if…then' test (producing a truth-value or a probability-value). It primarily requires a conditional test producing a 'possibility-value' (*including* truth and probability see *Fig. 2* on page 17). The logical propositions 'if p then q' ($p \Rightarrow q$), 'q if p' ($q \Leftarrow p$) or iff p then q ($p \Leftrightarrow q$) have a truth-value. Modal logic adds a possibility-operator $\Diamond$ and a necessity operator $\Box$, but these operators are subordinated to truth-values (e.g. $\Diamond P \Leftrightarrow \neg \Box \neg P$ has a truth-value, ($\neg$ means 'not')). This thesis cannot accept this subordination, because it concerns truth (a probability) as a possibility (see *Fig. 2* on page 17), not the other way around. This thesis thus required a different possibility operator expressing that p *supposes* q ($p \Downarrow q$), to be tested introspectively as 'I cannot imagine q without p, but I can imagine p without q' (you may refer to it as a 'practical condition' to be distinguished from the linear 'logical conditions' $\Rightarrow$ $\Leftarrow$ or $\Leftrightarrow$). This is important in education, because if a teacher want to explain q, and the student cannot imagine a tacitly supposed p, (s)he cannot 'build' upon a shared supposition p. Your 'under-standing' of q depends on your ability to imagine p, and p possibly supposes still other underlaying suppositions (e.g. $p \Downarrow o \Downarrow n \Downarrow m \Downarrow l \Downarrow k$) hidden in the words used. For a teacher it is difficult wich of them is missing before a student may understand p. This becomes particularly critical if the subject is a more dimensional image or design, where logical contradictions are allowed perpendicular to the line of verbal reasoning.

[c] Democritus(~400BC): 'λογοσ εργου σκιη'.

[d] Blind people may use the sense of touch to discover space, but this impression is also two-dimensional due to the surface of their skin.

[e] Piaget unveiled the crucial role of the motoric sense in learning. See for example Piaget;Inhelder(1947) *La representation de l'espace chez l'enfant* (Paris) Presses universitaire de France

your eyes, feet or hands. You may extend these situational descriptions through impressions of touch, smell, hearing or associated memories. But, these impressions must stay within the line of verbal inference, they must be limited to details as side-roads of the 'story'. These details may be telling in a poetical sense, but they are not sufficient to design the content, form and structure of an environment that make many actions possible. Verbal language is suited to study the content of designs systematically, to express their intended functions in a brief, to realise them in a building process, to evaluate and to sell them, but not to make them.

Studying possible environments for possible actions requires drawing

A drawing shows objects surrounding the action, for example, perpendicular to its direction. You may say that a drawing is 'at right angles' to telling a story. In Dutch this expression is revealing, because 'haaks' (i.e. 'at right angles') makes it readable as 'Drawing is *at odds with* telling a story'. Shaping an environment for many stories is different than a storyboard. A storyboard puts *one story* in a sequence of *many scenes*. It requires a different kind of imagination to make *one scene* for *many stories*. Moreover, spatial design requires that this scene must fit in an environment of many scenes for many stories, separated and connected with each other through transitions where people themselves can decide what their next action will be. The construction must be stable enough to last for years instead of hours. The structure even may hide itself from the view of the users. However, the initial imagination of it by a designer requires a thorough understanding of a third spatial dimension whereby it is released from its original imagination through movement and time. Every design student will remember that the teachers stressed the need to draw cross-sections. How can one teach these abilities, which are so strange for a mind thoroughly trained in the use of language and linear reasoning? Drawing exercises are required to release the ties of language. Drawing is an intensive dialogue between you and the developing picture that is made by your disobedient hands. Mistakes are a source of innovation. They will change your thoughts and your imagination through the act of doing. They open up other possibilities than the intended ones, which lead to unexpected directions. A picture has more directions and it is closer to the senses than a linguistic expression. Drawing allows your observations to be more free from existing categories than speaking and writing. It allows imagining categories that cannot be named. The close observation of the human heart by Leonardo da Vinci in 1509 enabled Harvey to understand the blood circulation process in 1628. James Watt designed a commercially working steam engine 40 years before Clausius and Bolzmann could understand the steam engine's thermodynamic processes.

Educating design should start by drawing and modelling

Learning by doing is broadly accepted as the intention of design studios, in design education. The tightening requirements of 'scientific education', however, forced educators to start the studios with analysis before drawing. Initial exercises trained the students in writing. In one case I know, the use of pictures was prohibited. It worried me, to see the students extending the period of analysis, writing extended reports of poor scientific quality, before they started to draw in the last days of their studio. I was disappointed by the resulting designs, which were hidden behind the overwhelming standard graphic effects that are available at any computer. The evaluation of their projects seemed to be more interested in the selling of the idea than the content. If I asked the students which elements of the earlier analysis had been useful for their design, they could not name any. The teacher's remarks on the designs at the evaluation sessions that I have attended were always expressed in words, not in drawings. I even suspected some teachers were not able to draw themselves. They were probably educated through texts rather than drawings. I even questioned my own capacity to express the relevant questions in drawings when I read my first PhD thesis. Understanding a situation and its potentials, however, first requires time consuming drawing and redrawing , in order to become aware of the questions that are relevant for spatial design. Analysis must *follow* a preliminary design, in order to determine the relevant lines of evaluating research that are necessary to adjust the suppositions of a next design version. Design is a cyclic process of drawing, evaluating the drawing, and redrawing. Educating design should start by drawing and modelling, in order to be able to ask the relevant questions for further detailed analysis and design.

This thesis contains a paradox

This thesis demonstrates some possibilities to transcend the limits of language, but mainly through text. It may open up a vast area of research and study if this area is not primarily limited to the categories of spoken or written language. A drawing, then, must be recognised and developed as a scientific product in its own right. A drawing is a scientific achievement if it explains the intended content, form and structure properly. In this thesis, these 'orders of diversity' are elaborated as variables with values at the boundaries of language. This may make them accessible for traditional scientific evaluation, and it may invite traditional scientists to cross the threshold of their probability language into a world of possibility, which can be opened up through design.

10 Summary

English summary

This thesis studies the possibilities to diversify a human environment through means of design. Environmental diversity is primarily characterised through naming variables, as described in Chapter 3. Subsequently, an attempt is made to name their extreme values and – if possible – to identify an absolute value that may serve as a zero-point, from which the other values may have a determinable distance. However, many values that distinguish environments, at different levels of scale, are not quantifiable in this way, or even suitable to be positioned in a determined order. These variables, then, have an ordinal, or even only a verbal, character.

Identified values may appear in a drawing as legend units. Drawings with the same legend may still differ through the distribution in space of every legend unit, including its quantity. The distribution in space is thus a *second order* of environmental diversity. If the legend describes the content of a drawing, the dispersion in space of a legend unit – including its quantity - is nothing other than its form. This second order diversity of form, as it is elaborated in Chapter 4, can be applied to every imaginable legend unit.

Different environments within a room must be described through different values than those that are used to describe the different environments within a region. The variables, their values (i.e. content) and the dispersions of these values in space (i.e. form) are scale-sensitive. Therefore, this thesis distinguishes 12 levels of scale. Each level has its own variables and possibilities, in order to distribute their values in space. At every level of scale, the design means are different, and these differences are taken into account throughout the thesis.

Similar forms may be stabilised differently, through different 'structures' (Chapter 5). Structure adds a *third order* of environmental diversity, which is superimposed upon the first and second order. This thesis refers to 'structure' as 'the set of connections and separations that stabilise a form'. A structure is not always visible. At the lower levels of scale, 'structure' is commonly known as 'construction', but at the higher levels of scale, it contains 'infrastructure'. Structure enables functioning. If a structure is 'operational', it can 'perform' different functions. Function is thus a fourth order of environmental diversity (Chapter 6). Chapter 7, then, studies the diversity of intentions that are possible with similar functions, as a *fifth order* of diversity.

The sequence of content, form, structure, function and intention is not causal, but 'conditional', in the sense of 'not being imaginable without' the previous condition. A function is not imaginable without a structure, and a structure is not imaginable without (often tacitly) referring to a form. Conditional sequences are the main principle of this thesis. It distinguishes studying *possibilities* from studies concerning *probabilities*. This thesis is an attempt to play a language game that is different from empirical research: the language game of design (Chapter 1). Design does not *cause* a function, it *conditions* different possible functions, and serves different intentions. The methodological problems of such an enterprise are elaborated in Chapter 2.

Dutch summary

Dit proefschrift onderzoekt de mogelijkheden van milieudifferentiatie door ontwerp.
De verscheidenheid van milieus wordt daarbij in eerste instantie beschreven in hoofdstuk 3 door haar variabelen te benoemen. Vervolgens is een poging gedaan om hun extreme waarden een naam te geven en – voor zover mogelijk – een absolute waarde te vinden die als nulpunt kan dienen ten opzichte waarvan de afstand tot de andere waarden kan worden bepaald. Veel waarden die op verschillende schaalniveaus omgevingen van elkaar onderscheiden zijn op die manier niet te kwantificeren of zelfs in een bepaalde ordening te plaatsen. Deze variabelen hebben dan een ordinaal of zelfs alleen een verbaal karakter.

Benoemde waarden kunnen in een tekening als legenda-eenheden verschijnen. Tekeningen met dezelfde legenda kunnen nog verschillen in de spreidingstoestand van elke legenda-eenheid. De spreidingstoestand – waarbij kwantiteit is inbegrepen - is dus een een *tweede orde* van milieudifferentiatie. Als de legenda de inhoud van de tekening beschrijft, dan is de spreidingstoestand van elke legenda-eenheid niets anders dan zijn vorm. Deze tweede orde van milieudifferentiatie, zoals beschreven in hoofdstuk 4, kan worden toegepast op elke voorstelbare legenda-eenheid.

Verschillende milieus binnen een kamer moeten met andere waarden worden beschreven dan de waarden die verschillende milieus in een regio onderscheiden. De variabelen, hun waarden (inhoud) en de spreidingstoestanden van die waarden (vorm) zijn schaalgevoelig. Daarom onderscheidt dit proefschrift 12 schaalniveaus. Elk schaalniveau heeft zijn eigen variabelen en mogelijkheden om hun waarden in de ruimte te spreiden. Elk schaalniveau heeft andere ontwerpmiddelen en deze verschillen worden overal in het proefschrift in acht genomen.

Dezelfde vorm kan op verschillende manieren stabiel gemaakt worden met verschillende constructies of structuren (hoofdstuk 5). Structuur voegt een derde orde van milieudifferentiatie toe, bovenop de eerste twee. Dit proefschrift definieert ‘structuur’ als ‘de verzameling verbindingen en scheidingen die een vorm stabiliseren’. Een structuur is niet altijd zichtbaar. Op de lagere schaalniveaus wordt ‘structuur’ gewoonlijk ‘constructie’ genoemd, maar op de hogere schaalniveaus omvat het de ‘infrastructuur’.
Structuur maakt functioneren mogelijk. Als een structuur ‘operationeel’ is kan het verschillende functies vervullen. Functie is dus een vierde orde van milieudifferentiatie (hoofdstuk 6). Hoofdstuk 7 onderzoekt dan de verscheidenheid aan intenties die nog mogelijk zijn bij dezelfde functies als een vijfde orde van milieudifferentiatie.

De volgorde van van inhoud, vorm, structuur, functie en intentie is niet oorzakelijk, maar ‘voorwaardelijk’, in de zin van ‘niet voorstelbaar zonder’ de voorafgaande voorwaarde. Een functie is niet voorstelbaar zonder een structuur waarin zij functioneert, en een structuur is niet voorstelbaar zonder een vorm aan te nemen. Voorwaardelijke volgordes zijn het algemene principe van dit proefschrift. Zij onderscheiden het onderzoek naar mogelijkheden van het onderzoek naar waarheden of waarschijnlijkheden. Dit proefschrift probeer een ander taalspel te spelen dan dat van empirisch onderzoek: het taalspel van ontwerp (hoofdstuk 1). Ontwerp *veroorzaakt* niet een functie, het schept *voorwaarden* voor verschillende mogelijke functies en het dient verschillende intenties. De methodologische problemen van zo’n onderneming zijn uitgewerkt in hoofdstuk 2.

Afterword

Dear readers, wait a minute. The angry young man attempts to take over my keyboard.

> *Dear old man, where are our ideals to change the world? Did you forget our idols, Chris van Leeuwen and Aldo van Eyck, who both sought the potential boundaries of space in order to produce differences? Did you forget their lectures and those of Carel Weeber, Frans Maas, Niels Luning Prak? Did you forget Jos Louwe and the 100 propositions of Sharawagi? Did you forget Job Tarenskeen's innate design skills (though he exchanged space for music), Pieter Schrijnen's social involvement, Joost Schrijnen's drive for practical realisation, Evert Croonen's humorous putting things in perspective, Peter Paul van Loon's rational and systematic approach, Mick Eekhout's visionary inventions? Did you forget Robbert Jongepier teaching us the first steps of design and proper handwriting (at last), the verbally gifted design teacher Leo Tummers, our engaging graduate mentor Peter Pennink, the geographers Chris van Paassen and Rob van Engelsdorp Gastelaars giving access to the humanities at the other universities, the lucid researcher Dirk de Jonge as the Socratic teacher between the rules unravelling our false suppositions, the sociologists Cornelis Saal and Jan Berting, convincing us that social understanding is crucial to change anything in the world? Where is this all in your thesis? You skipped nearly everything about the sociological basis of our profession: my beautiful functional distinctions, my psychological analyses, my overview of the humanities, the philosophical inspiration of Wim van Dooren, the anarchist. You have become a technocrat! Did you forget the national office for spatial planning RPD, the inspiring environment with Eo Wijers, Jan van Donselaar, Götz Nassuth, Peter Dauvellier, Everhart Reckman? There I wrote my thesis and there I am now writing its follow-up, 'Applied study on environmental diversification'. Wait and see, no more theory! Application, old man, application! We are going to clean up the nation with Peter Dauvellier's Global Ecological Model and my brand new study. We will involve all the people, we will convince them with excellent plans. What is your plan, what did you realise, what do you expect to gain with another thesis so theoretical, so technical?*

Dear readers, thank you for waiting. The angry young man is gone. He is jealous of my thesis, and he is not very honest. He is not so eager to show applications, but his employers and the people he mentioned ask for direct solutions. He wants to please them, because he loves them. He knows, however, that the box cannot be closed if you do not straighten the bottom stones, and everybody brings new stones. There are too many for his box, and he regularly retires for long periods in his room full of stones with his magic box. Nobody knows what he is doing there, and he is unable to explain. He has to choose, but he cannot choose due to a lack of experience. He does not dare to refuse the stones that look so precious. Let me now confidentially make a prognosis of what will be his future.

Years of practice

His 'Applied study on environmental diversification' will become a failure. Nobody will read its extended elaborations and its ugly pictures about the stones he brought into the field in order to build the regional structures that his employers expect. In a bureau for urban design in the North of the country, where he will be employed after the RPD, they will laugh about his box and his impressive PhD title (so unusual in the field of design), when his first design appears even not to contain enough parking places per dwelling. He will work too slow for the pace of the company. Intending to improve his design, he will see the contours of his unfinished plan (stripped by financial experts) already laid out with pickets in the field when he passes the area in the train next morning. The bureau will go bankrupt and he will start his own bureau named MESO in order to find the right middle between theory and application. It will exist approximately 20 years, producing very diverse proposals and studies (e.g. regional energy plans, extensive wind tunnel experiments with TNO[a], future scenarios and an ‘image quality plan’ for the Amsterdam district ‘De Baarsjes’, an important break-through in his development).

Back into ecology

In the mean time - to his surprise - he will be invited to apply for the Ecology Chair to succeed Chris van Leeuwen in the Faculty of Architecture of the University of Technology in Delft. From more than 100 candidates he will be chosen, even though he pretends not to know enough about ecology. It will last 5 years before the Faculty can finance a new Chair. He will use this period to study authoritative handbooks of ecology, discovering that *nobody* knows enough about ecology. He will suspect that there is something missing in the common scientific method. He will realise that the heritage of van Leeuwen *generates* the observed diversity instead of *reducing* it, as is usual in common *generalising* scientific thought. Is there something wrong with empirical science itself, when it is confronted with context-sensitive diversity, possibility and design? And if so, what is it? Anything that is able to be generalised seems to be generalised already; the unique, context-sensitive issues remain. This methodological question will bother him for years to come.

The academic sinus

When he enters the University in 1986, he will meet his professors from 1976 who will now ask to be addressed by their forename. The Faculty will be exactly the same Faculty that he left ten years before, except it will now have been increased in size. He will learn the peculiarities of management, for example, the rule to make a U-turn about every 4 years. Every new Dean will change everything when confronted with the failures of his[b] predecessor. He will arrive at the point where the predecessor of his predecessor had arrived already 8 years before, a context that not many people will remember anyhow. Therefore, nothing changes in the long term. The young man will discover this regular fluctuation only after at least 12 years of involvement as one of the predictable sinuses of management. This will reduce his initial stress, resulting in a happy rest of his academic life.

The first U-turn

Here begins my own story. In the first period as a part time professor I attempted to introduce the box of the young man writing lecture papers and computer programs, but then, fortunately, the first U-turn emerged in 1990. My courses and lectures were abandoned, in order to obtain a brand new start with ‘problem based learning’, so I could learn from the new study programme. This case based educational method had been a great success in the Medical Faculty of the University of Maastricht, and their educational professionals came to teach us the method to reform the system that our Faculty had already practiced for decades in its design studios. The Dean asked the most experienced professor (i.e. Carel Weeber) to organise the first year of the brand new education method with the youngest professor at the time (i.e. me). The resigning fellow teachers taught me the educational sinus following the one of management. If you do not succeed in obtaining sufficient commissioned hours in education, then you will have enough time to participate in the boards that *organise* the new education. After some time, it will result in an increasing number of commissioned hours for your own course, filling the hours of the abandoned courses of the others. It gives, however, the others time enough to succeed you (being too busy) in the educational boards, where they prepare the next U-turn.

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[a] The Dutch national institution for applied technical studies.

[b] This masculine personal pronoun is chosen because all Deans were masculine, except the last, announcing the revolutionary intention *not* to change everything.

Two cupboards

By collecting new literature and writing new lecture papers and computer programs, and being inspired by my parallel MESO-work, I was wise enough to store the old course material in a cupboard. Let me name it cupboard A. The same occurred after the next U-turn. As usual, after 4 years, I was asked whether I could make a new course for a brand new education programme. I stored the abandoned courses with their literature, sheets, lecture papers, test questions, exercises, assignments and computer programs in cupboard B. I opened cupboard A, which could be adapted easily into a course with the demanded title, because the next Dean had finally arrived where his predecessor began. Thus, it takes 12 years to become acquainted with the AUBUA-system, in order to make substantial progress in improving the subjects of A *and* B. I must, however, report one remarkable exception on the discontinuity of educational titles and contents of lectures. From the beginning, I became involved in a lecture series 'Environmental Impact Analysis' at the Faculty of Civil Engineering, coordinated by Peter van Eck. He managed to safeguard the continuity of this course through all of the 25 years I was employed at the University. It was the only course I witnessed that lasted so long, and the yearly adaptations and improvements of the lectures and the exercises resulted in the best lectures of my career. I was very grateful to Peter that my last lecture at the University could be given in his course at the Faculty of Civil Engineering.

Different titles for the same content

I now understood the background of the irritations of the angry young man as a student, refusing to attend courses of different professors telling the same thing, while the titles of the courses were different. With a group of students called 'Sharawagi', he had made lecture papers from these similar lectures. Sharawagi then sent copies to the other professors, in order to inform them about the overlaps. I now understood that the professors did not produce lecture papers concerning the detailed content of their course, because it had to be changed so often. They simply could restrict themselves to change the title of the course, continuing to use the same sheets or powerpoints. Managers like appealing titles to sell their success. The presentation sells, not the content.

Overlapping shadows of doing

The consequence has been, however, that nobody knew what content hided behind the promising titles, except the students. The students wisely did not inform the boards about the extensive overlaps, because it is convenient to pass exams with similar questions. Dean Jürgen Rosemann once assigned MESO to study the contents of the first two years of the Faculty in more detail than just titles. This study unveiled that the Villa Savoye by Le Corbusier was discussed and tested 17 times in different courses. The required readings amounted to more than 150 books, of which little could be recognised in the tests. Instead of studying them, the students could better study the tests of previous courses, because the same questions returned, alternating in a predictable way. In design oriented education, the studios as a kind of learning by doing education, are more appreciated than lectures and empirical sources that partially deepen subjects. Science and the humanities support little in the *making* of a context-sensitive spatial design, requiring simultaneous decisions about content, form and structure, estimating their possible functions every second.

NNAO

This takes me back into the methodological question already bothering the young man. What kinds of studies and research are required for spatial design? The scientific board for government policy (WRR) had published two reports on national *policy* directed scenarios in 1983.[a] The WRR reports, however, also distinguished the modes of reason in policy, empirical research and design, which the young man distinguished in his thesis (further elaborated in this thesis, see *Fig. 2*). In 1985, Dirk Frieling and Kees Rijnboutt subsequently initiated a project on four national *design* directed scenarios for 2050: 'the Netherlands now as a design' (NNAO). Four scenarios were made: a 'Zorgvuldig', 'Dynamisch', 'Kritisch', and an 'Ontspannen' scenario (i.e. a 'Meticulous', 'Dynamic', 'Critical' and 'Relaxed' scenario, according to the programmes of Christian Democratic, Liberal and Socialistic parties in the Netherlands of the time, and an own optimistic 'Technocratic' NNAO view). The scenarios were made by four different research bureaus. The resulting programmes were elaborated into a design by four different design bureaus. MESO made the Relaxed scenario, calculated different effects of the scenarios, checked the designs upon the programme resulting from each scenario, and made simple computer programs in order to be able to do so. Many reports and publications appeared[b], and the project culminated in a large NNAO-exhibition in Amsterdam.

Momentum

With 8 Urbanism and 4 Industrial Design students of the University of Delft, and with Alexander Kyrkos as the leading designer and C-programmer, I developed a computer game 'Momentum' for NNAO. This computer game enabled anybody to design her or his own scenario.[c] At any design intervention, it reported which of the four political parties would be most satisfied, showing their representatives as laughing or crying faces ('emoticons' as you would name them now). I clearly remember the evening with one of the students, Wient Mulder, on which we suddenly managed to develop an algorithm to let them laugh, cry or something in between. This algorithm was based on a study by the University of Amsterdam, which was focused on the spatial suppositions of political programmes since WWII. At the exhibition, four politicians played the game simultaneously on stage, declaring to agree fully with the computerised emoticons they represented. We apparently had interpreted their suppositions correctly.

Suppositions of imagination

This NNAO experience changed the box of the young man into the idea of a successive conditional construction of suppositions. Any cause is a condition for something to happen, but not every condition is also a cause. It clarified the relations between probability, possibility and desirability, as the territories of empirical research, design study and policy. I managed to *draw* them for NNAO as the including and overlapping sets of *Fig. 2*, but I underestimated the resistance against this obvious scheme. Authorities defend their territories as the young man already described in an essay on request of Wim van Dooren.[d] The conditional sequence appeared to be applicable in many areas: the modes of reasoning (probable, possible, desirable) the orders of difference (content, form, structure, function,

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[a] WRR(1981) *Beleidsgerichte toekomstverkenningen* (Den Haag) Wetenschappelijke Raad voor het Regeringsbeleid

WRR(1983) *Beleidsgerichte toekomstverkenning. Deel 2: Een verruiming van perspectief* (Den Haag) Wetenschappelijke Raad voor het Regeringsbeleid

[b] NNAO(1986) *Ontspannen scenario* (Den Haag) MESO

NNAO(1987) *Nieuw Nederland 2050 deel I achtergronden* (Den Haag) SDU

NNAO(1987) *Nieuw Nederland 2050 deel II beeldverhalen* (Den Haag) SDU

NNAO(1989) *Nieuw Nederland, Nu Nijmegen & Arnhem Ontwerpen* (Den Haag) SDU

NNAO(1989) *Nieuw Nederland, proeve van een investeringsstrategie* (Den Haag) SDU

[c] Jong(1985) *Programma NNAO scenario* (Den Haag) Stichting Meso and Sociaal-geografisch instituut UvA

Jong(1986) *Energiebijlage Programma NNAO scenario Bijlage 3* (Den Haag) Stichting Meso and Sociaal-geografisch instituut UvA

Jong;Kyrkos;Reijden;Smink(1989) *Staat van Momentum Fase C. Workshop Momentum (Delft*) Faculteit Bouwkunde TUD

[d] Jong(1978) *Autoriteit en territorium* (De As, anarcho-socialisties tijdschrift) zesde jaargang, nummer 31

intention), and the layers of function (space, ecology, technology, economy, culture, management). In 1992, I published an attempt to unravel an all-embracing fundamental sequence of conditions as suppositions of imagination.[a] This elaboration of the young man's fascination on conditional thinking, instead of causal thinking, may be my greatest achievement, but its nearly mathematical strictness still contained gaps. The philosophy professors of our University, Peter Kroes and Marc de Vries, refused my attempt to elaborate it as a thesis. Marc de Vries was most clear about the reason. He missed practical examples as an empirical foundation. The current thesis may provide some applications before I can resume this even more fundamental work.

Suppositions of the audience

Before I became involved in the NNAO-project, I had some experience in Basic computer programming. Designing the complex computer game Momentum in C-language, however, made me even more aware about the necessity of conditional thinking while designing. A computer is really a blank slate, a tabula rasa. If you do not inform the machine of *all* suppositions or conditions, it immediately reacts with 'error'. Many hours can pass before you find the missing line or sign in the source code. You are not aware of all necessary suppositions, so self-evident in human communication. The experience of repeatedly stagnating computer programs made me conscious of the possibly of missing lines while teaching students. A human audience will, however, not react with 'error'. You thus never know if it shares all the suppositions that are required to interpret your words adequately.

Interest-based suppositions

Making and evaluating the future scenarios, I also realised how many hidden suppositions there are. There are numerous assumptions about the physical, ecological, technical, economic, cultural and managerial conditions, which are usually taken for granted as ceteris paribus suppositions. They determine whether a scenario is possible at all, but their continuation in time must be questioned. Changing any of them may change the scenario as a whole. For example, for the Relaxed NNAO Scenario, I assumed that fusion power would become the future energy source, but this soon appeared to be a bold supposition, as Kees Duijvestein already mentioned with some good-natured scoffing. Later I replaced the fusion-assumption into the supposition that solar power would become the final energy-source. The first suggests a centralised, the second a decentralised production with many consequences for any scenario. Both suggest future energy-abundance. Assuming an abundant availability of energy, however, undermined the usual advice of economical energy-use: thermal insulation, wind energy and so on. I attempted to refute the common supposition of future energy scarcity through a simple calculation, but this did not convince the professionals. 'Algebra is also an opinion'. It undermined the common suppositions on which the livelihood of current environmental professionals are based. Some truths or technological expectations may be rejected if they endanger short term human interests.

The paradox of planned innovation

Fascinated by interest-based suppositions, I attempted to doubt *any* supposition, and I discovered many common suppositions that I did not share. The increasing commercialisation of science destroys its core: doubt. You cannot sell doubt. People pay for certainty. Even if you can falsify its foundations, the opinion of the majority offers more certainty. Marketing is based on statistics, but evolution rewards rare exceptions. Innovation cannot be forced through a research programme, but you cannot obtain funding without a research programme either. I was involved in, or witnessed the writing of many research programmes on the level of the University, the Faculty, its Department and my Chair, but I never witnessed any innovative result. Innovation requires skipping at least one common supposition, but a research programme is based on the consensus of the committee writing it. It is a compromise, resulting in an average 'feeling' of old, wise men, neglecting the

[a] Jong(1992) *Kleine methodologie voor ontwerpend onderzoek* (Meppel) Boom

exceptions. An 'innovation programme', thus, is a paradox in itself. If innovation can be programmed, it cannot be innovative.

Technology as a driving force

Technological innovations, however, changed the world more radically than anything else. The wheel, the iron, the art of printing, the steam engine, electricity and the transistor changed economies, cultures and the division of political power, not the other way around. Scenarios are still made assuming that a government, a culture or an economy are the driving forces of technological innovation. Wilkinson[a], however, argues that progress is the result of changing conditions, ecological adaptation, and poverty. This appealed to my conditional thinking. I did not deny some positive *causal* effect of economy, culture (including the subculture of empirical research) or government on innovation, but I could not imagine this effect outside the physical context, without the boundary conditions of ecology (including resources, demography *and* available devices, technology).

The disadvantage of politeness

Innovation may require disobedience, rejecting common suppositions, even if they are profitable for current managers, professionals, industries and traders. In my opinion, my colleague professors were too obedient, too friendly with the managers that gradually took over their organisational tasks, rating their production instead of their potential innovation. The simple suppositions of management can be astonishing. Innovation may require many failures first, and success may appear to be false at last. 'Success' then will be forgotten soon. In my opinion, my colleague professors were also too friendly to each other, hesitating to criticize. Part time professors may meet each other in practice, and faultfinders are not popular in a production team. A University, however, is not a mass production team. It is an innovation team, requiring difference and mutual critique. Its product is heterogeneous. Students are different, full of different potentials, and consequently heterogeneous as a graduated 'product' of personal academic education. The products of academic study should make a difference, they should be risky, improbable, with often unexpected side effects, but I had to conclude they were not.

A second sinus

The producers apparently attempted to fulfil expectations, producing fashionable short-term solutions, which will create new problems in the future. Studying these disappointing products, I suspected a scientific sinus of about 30 years. I recognised the attempts of thirty years ago, by putting the repetitions into perspective. I realised that any research or study requires a long term scenario, in order to make its suppositions explicit, and some historical awareness in order to avoid repeating mistakes. I politely started to criticize the lectures and the papers of my colleagues, observing the reactions with scientific interest. The reaction was mainly no reaction, sometimes irritation, and it was rarely characterised by a spirit of appreciation, curiosity, counter-arguments and counter-critique. This became my selection instrument for ´true academic friends´. I was no longer invited for managerial tasks, I did not receive hopelessly useless emails that needed to be answered, and this saved time. My most productive academic period began.

Dirk Frieling

In the nineties, I temporarily occupied several chairs of the department of Urbanism at our Faculty of Architecture, in order to keep them occupied until a proper successor could be found. I suggested Dirk Frieling (the 'Founding Father' and developer of the Dutch new town Almere) to join our department as a professor, and he did. He had commissioned MESO with assignments for NNAO through very precise letters, exactly leaving open what had to be left open. The results were returned with accurate remarks in the margins and sometimes devastating, but always distant criticism, in a beautiful handwriting. He managed to put your

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[a] Wilkinson(1973) *Poverty and progress* (London) Methuen

efforts in a wider, physical and social, nearly philosophical perspective, having a good nose for the context of the time. An avalanche of initiatives stirred up the Urbanism department and the Faculty immediately after his arrival. I witnessed how he convinced the right sponsors, through his surprising schemes that were sketched with a sure hand at the table of the right restaurant, as if these schemes put *their* ideas in a wider and promising perspective. Once the funding had been arranged, nearly everyone in the department became involved with challenging commissions that they could not refuse. I received a perfectly hand written note in the style I knew so well, containing a budget and the request to compare some designs for the Randstad in the framework of a vague project named 'The Metropolitan Debate'. Debate! But, how to analyse this heterogeneous set of plans which varied from vague into very precise, with different population capacities, legends, contents, forms, structures, functions and intentions? He knew how to challenge me. Graphic designer Ellen Ali Cohen (I knew her from my 7th year; we played in the same street) made an up to date and very precise map of the Netherlands. We married, but this had more reasons than the map. With Alexander Boelen, my PhD candidate, I discussed the method and he prepared the overlays. It is a great pity that he did not finish his PhD. Without intermediate reports through the years of his employment, he finally offered to me an extensive concept thesis, but he could not explain the method otherwise than naming it 'research by design' at one page. It was a low point in my career to realise that I could not explain it properly either. Only seven years later (editing Ways to Study with Theo van der Voordt), I managed to give it the right place in relation to empirical research. Nevertheless, the current project was the very beginning of a method, and Alexander contributed a substantial part to it. Apparently surprised by our first report[a], concerning the comparison of four plans, Dirk Frieling reacted sparingly: 'It may work. Here are some other plans.'.[b]

The Metropolitan Debate

The Metropolitan Debate appeared to be the forerunner of the still existing society of large municipalities named 'Vereniging Deltametropool'. Many studios and workshops followed in different parts of the country, which were meticulously prepared by Frieling's extensive questionnaires. The questions were so challenging, that the response from the nearly 1000 participants from all parts of the country and from most diverse professional backgrounds was higher than anyone expected. Within a week, every participant received a statistically elaborated summary of the answers and a new questionnaire, which forced the participants to make their position gradually more explicit. After four questionnaires, the workshop could start with well-prepared participants. You could choose a project from the list of Jan Brouwer, a location, and try to realise it there. Then you could attempt to obtain administrative approval at one table and financial funding at another table, based on a scientific impact analysis at still another table. If you succeeded, than your project was put on a large map, while four politicians simultaneously defended the maps based on the scenario of their own party at the remaining side of the room. Looking at the map with projects, they could ask for a referendum, which eventually skipped your project. The game of negotiations was so exhausting, that I sometimes left halfway, but Dirk was indefatigable. The day ended discussing the resulting map: 'Is this the country you want to live in?'. Frielings speeches were challenging, and I once exclaimed 'What a nonsense!', explaining why I disagreed. He answered as a true academic friend: "Taeke may be right in this respect, but …", and subsequently he summarised where I was definitely wrong.

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[a] Jong;Boelen;Ali Cohen(1995) Analyse van 4 ontwerpen voor de Randstad(Zoetermeer)MESO
[b] Jong;Dieters;Boelen(1996) Voorlopige morfologische analyse van 12 plannen voor de Randstad(Zoetermeer)MESO
Jong;Achterberg(1996) 25 varianten voor 1mln inwoners (Zoetermeer)MESO

Comparing designs

I could not fulfil Frieling's request to make a computer program that reported the regional impacts of any arbitrary project, based on empirical evidence. The context-sensitivity of spatial plans makes every project an exception to the rule. Generalised 'knowledge', with the *same* (ceteris paribus) suppositions, but in *different* contexts, may harm local potentialities. However, the comparison of *different* designs in the *same* context, with the same suppositions, could be useful. With the experience of NNAO and the Metropolitan Debate, I could accept a commission from the municipality of Almere, to compare the ecological effects of four designs concerning an extension of 50 000 inhabitants. My experience in ecology, however, had taught me that strictly empirical research is mainly concerned with the impact on the chance of survival of one species, and that the impact on communities or ecosystems always must be based on suppositions about their 'value'. This value, then, must be compared with the value of human projects. This brought me to the solution to take *rareness* and *replaceability* in order to evaluate both ecosystems and human projects. Rareness could be expressed in the distance in kilometres until the next example can be found, and replaceability could be expressed in the number of years required to realise the same kind of project or to develop a similar ecosystem.[a] This measures allowed me to put the ecological communities *and* human projects in the same graph depicting their position in spatial rarity and temporal replaceability.

A speech

Comparing designs may offer a bridge into empirical research, but this still does not solve the question: what role can empirical research play in the *making* of a design, other than preparing its programme beforehand, and evaluating its result afterwards. In 1995, I had the honour to pronounce the annual 'Diesrede', the speech on the occasion of the anniversary of the University (Dies natalis), which represents the state of the art in one of the Faculties. Every year, another Faculty has the honour to do give the speech, and this time it was the Faculty of Architecture's turn. Our Dean at the time, Jürgen Rosemann, decided that I had to give the speech. In one of the previous U-turns, our Faculty had dismissed its gradually isolated institutions for empirical research on architecture, urbanism and housing. The design chairs argued that the studies of these institutions were useless for design, and they wanted to develop their own ways to study.

A University audience

I knew the doubts of the other faculties concerning the scientific competence of our Faculty. In the University, the debate concerning our competence emerges once about every 10 years, and always results in the obligation to implement a substantial mathematical course in the education of the Faculty. With Jan Aarts from the Faculty of Applied Mathematics, I had developed such a course, but this time-consuming component of the education disappeared by the next U-turn. Jan dealt with his disappointment writing a book on geometry full of linear matrix algebra[b], convincing me of the difference with architectural geometry. Jürgen thought that I could convince the university community of our scientific value beyond mathematics. I did not always agree with Jürgen, but he appeared to be a true academic friend, and he gave me total freedom to determine the content of my speech. It was entitled 'Systematic transformations in the drawn design and their effect'.[c]

Transformations in drawings

My father, a nuclear physicist and retired professor of fine mechanics from the Faculty of Mechanical Engineering at our University, was proud but worried. I inherited his professor's robe, but he knew the young man with his bold statements. He offered me the opportunity to practice with a small audience, and gently gave advice as a father does. He took care of my

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[a] Jong(2001) *Ecologische toetsing van drie visies op Almere Pampus* (Zoetermeer) MESO
[b] Aarts(2000) *Meetkunde. Facetten van de planimetrie en stereometrie* (Utrecht) Epsilon Uitgaven
[c] Jong(1995) *Systematische transformaties in het getekende ontwerp en hun effect* (Delft) Diesrede Technische Universiteit

presentation and reproduced my sheets. The content, however, was mine: designing is continuously adding dots, lines, surfaces or volumes to a drawing, comparing the result with the previous stage. Any transformation of your design has an effect that can be evaluated. You can distinguish different kinds of transformations systematically. Their effects may be suitable to be generalised. I showed examples produced by our Faculty at many levels of scale. It was a success, and my father was reassured. Jürgen could now ask for his university funds without shame.

Methodology

However, I was not so reassured myself. Is designing nothing more than drawing and comparing drawings, 'precedent analysis'? What about possibility-search? Later on, another Dean, Hans Beunderman, who was apparently urged by Dirk Frieling, commissioned me to develop a methodology book for the Faculty, concerning design-related research and study. He also commissioned me to make a computerised database of graduate designs. The computer program was overtaken by Google, but the book was used in every semester of the education until the next U-turn. This project became a success, thanks to my co-editor Theo van der Voordt. Theo is a meticulous, irreproachable empirical researcher, and I could quarrel with him as a true academic friend. He made the book acceptible for both designers *and* researchers in the Faculty, a unique achievement. It was entitled 'Ways to study and research urban, architectural and technical design'.[a] The word 'study' was intended to include design itself.

Ways to Study

Based on our request, fifty authors from our Faculty wrote a chapter for the book, explaining how they executed their research and study. Herman Hertzberger agreed to include two of the most impressive chapters concerning how to design. Even Hugo Priemus promised to write a chapter about strictly empirical research as the only way into scientific progress. Hugo Priemus was our former Dean, and director of the research institute that became the national authority on housing, after its separation from our Faculty. He was well-known from television in times of real estate crises, and was a confirmed empirical researcher. He was, however, so busy, that I proposed to write it for him as a clerk does for the President. "I know exactly what you want to write" I boasted. He smiled. He knew how much our opinions about research and study differed, and how little I had published compared to his astonishing production. He handed me a pile of authoritative methodology books, and I wrote his chapter. "Is this what you wanted to write?" He hesitated with a frown. "…Yes". "Then sign for it". "…How could I? You wrote it. You must be named as the author". "Me? Never! I do not sign for such nonsense!". I immediately felt regret for this bold statement, but Hugo smiled. "Let us both sign for it." This was a great honour for me, but I hesitated. "In that case, I have to add some remarks." Hugo agreed with the result and to the great surprise of Theo, our book included a chapter written by two authors more opposed to each other than anyone in the Faculty could imagine.

Doctorate ceremonies

Some years after my Diesrede, I was invited as a member of the University Board for Doctorates. I accepted the position as a great honour. It included regular meetings with the Rector Magnificus, the Deans of the other Faculties, and the obligation to chair a part of the promotion ceremonies on behalf of the Rector. In approximately ten years, I chaired some 400 ceremonies, mainly and intentionally from other Faculties than the Faculty of Architecture. I met the candidates beforehand, and they explained to me the content of their thesis. I chaired the promotion committees with professionals from all over the world, judging the defences of numerous candidates. I loved the ceremony, and the form of attack and defence as a critical academic debate. The person who defends or attacks is no longer

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[a] Jong;Voordt(2002) *Ways to study urban, architectural and technical design (*Delft) DUP-Science
http://team.bk.tudelft.nl/Publications/2002/Jong(2002)WaysToStudy(Delft).pdf

important, the subject matters as an object of scientific doubt. The research competence of the candidate is no longer the issue, but her or his ability to defend the work. Any thesis contains a table of propositions. Some of them represent the most risky part of the thesis, but others must represent subjects beyond the thesis. The propositions should be 'attackable'; Popper would say 'falsifiable'. The doubt always remains. It is the quality of the defence that counts. I enjoyed these sessions, and as a chairman, I could prepare the candidate to regard it as a game of defence and attack. "Humour is not forbidden, as long as it concerns the scientific subject. Any joke changes suppositions during the joke, and that is precisely the task of science." Instead of frightening the candidate, this appeared to relax her or his nervousness. I could then stimulate the committee to attack strongly and sharply, and not hesitate to say "Esteemed Promovendus, on page … you write … What a nonsense! …", which enabled the candidate to say "Highly esteemed opponent, you may be right in this respect, but …", and subsequently summarise where the opponent is definitely wrong. It was not difficult to change the religion-like style of the ceremony into an entertaining play, with impressive clothes and clauses. But, this transformation also resulted in the debate hitting the core of the scientific issue, and pushing the questions to their limits. A prescribed decorum helps to separate the issue from the person. Even a defeat is a victory for science. In 2011, I finished my membership with the Board for Doctorates, in order to be able to defend my own thesis, and to change my role in this beautiful academic ceremony, as it lives on in Delft.

The context of technology

From this experience, I learned the state of the art of technology in many of its branches. I was impressed by the thoroughness of the specialised theses, the prominence of mathematics, and of empirical research based on creative experiments. I enjoyed witnessing scholars force nature into exceptional states. This cannot be done in the humanities. I witnessed the emergence of bio-mimicry, which was focused on the increasing fascination of technicians on what is possible in biology. I asked the committee repeatedly "We still do not know much, do we?". They always agreed. Their modesty impressed me more than my own faculty's focus on fame. I developed some disdain about the products of architectural celebrities. Their experiments scored in cultural publicity, but not in amazing innovation. Winy Maas (MVRDV), however, appeared to be visionary with ideas such as the improbable Netherlands Pavilion at EXPO 2000, ten years before including nature in buildings became a serious object of research. Our department of Building Technology is inclined to creative experiments by Mick Eekhout, Karel Vollers and Kas Oosterhuis. In my department of Urbanism, however, history, and increasingly also management ('the process'), ruled the spirits. However, the results of the studios disappointed me. I suspected a lack of drawing capacity in the students *and* the teachers. Designers left the department in favour of text writers, who won the race into the accepted scientific journals. The only traffic engineer, Boudewyn Bach, retired. In practice, urban design lost ground to civil engineers, architects, landscape architects and real estate managers.

Education takes time

In 2000, the lack of urban technology was recognised in the department of Urbanism, and I started to prepare a course. After Ways to Study, my educational obligations were increased to 16 courses per year, but I managed to computerise them, thanks to my private secretary, Marlies Wenmeekers. She had some feeling for computer programming. Linda de Vos-van Keeken, the amazing head of the amazing secretariat of the department of Urbanism, supported me in obtaining the unique position of a professor with a private secretary. In ten years, approximately 4000 students made a website and published their take-home exams on the Internet. I judged them based on 5 to 25 criteria, and I published the specified marks on the web, in order to enable the students to recognise their strengths and weaknesses. Making a personal website appeared to be appealing for the students, because the first commission entailed the publication of earlier own design work. Having a personal website with your own work is an advantage for applications and personal publicity. Other advantages of this system of examination, were the motivation to make projects clear for everybody to understand, and the fact that I became acquainted with the achievements in the studios, which were presented as earlier design work. The rest of the commissions could then contain questions about the methodological or technical characteristics of the designs, and their strengths and their weaknesses, from the perspective of what the students learned in the course. Plagiarism was excluded, because any website was focused on the individual's own design work. I will now go into some detail about the urban technology course, because it shows the requirement of time to make a proper design-related course.

Educating Urban Technology

Before I prepared the course on urban technology, I thoroughly studied the lecture papers of Boudewyn Bach. I transformed the calculations into interactive Excel sheets, and I made many new clarifying images. I supported Boudewyn Bach to preserve his heritage for education in a final publication, but this beautiful book was too expensive for the course.[a]
I made my own cheaply downloadable lecture paper on urban technology. Every year I found new subjects missing in the course, and it was difficult to determine how to offer them in the right (conditional) sequence. In nearly ten years, the lecture paper expanded to 720 pages, with 1133 figures and 400 test questions, which frightened my colleagues and the students.[b] The student's reward decreased from 6 ECTS to 5, and from 5 to 4 ECTS, due to several U-turns with priority for management skills. But, it survived until my retirement. It finally included sun, energy, wind, noise, water, traffic, earth, land preparation, life, ecology, nature preservation, living, population density and legends for design with lectures, questions, downloadable powerpoints, videos and interactive computer programs for every chapter. Some computer programs had to be made as an executable file, but most of them could be offered as Excel files, enriched by Visual Basic routines and interactive sliders. They function at any computer. Every formula that was developed is shown and accessible for improvements. The students learned the ability of calculations to undermine popular beliefs. They also learned that technical calculations have their own dubious suppositions (parameters). You can doubt them and then ask the right questions. Particularly Asian students enjoyed the mathematical operations. Some of them even added valuable components. Making them was a great joy, but it took me approximately 2000 hours.

Breeding *awareness*

The educational goal of the course was primarily to make the students *aware* of the many technical problems they may meet in the urban design practice; it was not to make them specialists themselves. The main aim was to make them less vulnerable in the company of specialists, but there are many specialists in the field of urban design. How to cope with that multitude, and how to cope with a lecture paper that frightens students by its shear size? The primary requirement is to become able to find what you need. Google can help only if you know the right key words, and if you trust the diverse content of the Internet. The lecture paper should teach you the right key words, but this requires a systematic structure to find your way. The students had to learn how to navigate through the lecture paper. The navigation itself had to be exercised, in order to become familiar with the structure of the paper. A great means to exercise navigating through the extensive lecture paper was a multiple choice open book test of 20 questions that preceded every lecture, and concerned the subject of the chapter that would be explained *after* the test. The reward was a minor bonus in the final mark of the course (primarily based on the websites that were submitted at the end of the course) but the effect was remarkable. The students came in time and took their lecture papers with them. The lecture began with 20 minutes of silence, while students eagerly navigated through the extended lecture paper, forced by a new question that appeared on the screen every minute. The attention for the lecture increased, because it

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[a] Bach(2008) *Stedenbouw en verkeer; Urban design and traffic* (Wageningen) CROW
[b] Jong(2009) *Sun wind water earth life living, legends for design* (Zoetermeer) lecture paper

provided the answers at unexpected moments. The students saw it as a sport to reach high scores, without having to be nervous about the effect in the final mark.

Back into ecology

The teacher, however, doubted the contents, particularly concerning ecology. For a short period, I was a member of the board of the Society for Landscape Ecology (WLO). This membership gave me the opportunity to become up to date with the state of the art in this branch of ecology. I edited a book with Jos Dekker, including contributions to 3 WLO-symposia with 32 authors divided in 3 sections: Nature, Town and Infrastructure.[a] I became acquainted with the culture of the ecology department of Wageningen University, and Jos bridged the difference between the ecology department in Wageningen and the Urbanism department in Delft. He became a true academic friend. In my lectures concerning ecology, I distinguished 5 types of ecology, which were related to different Universities in the Netherlands. The majority of the authors from the University of Wageningen (mainly filling the section ‘Nature’) were apparently related to one of them (but not as I expected according to my lectures), following the National policy of ecological networks that were funding them. The German peer judging the content, made the interesting remark that we overlooked the extended German literature on the subject. I began to read more German literature.

An ecology of scientific subcultures

The WLO culture, with its own Dutch journal, was very different from the culture of NECOV, the other ecological society that I knew, as a member. Their cheaper symposia were full of posters from PhD-candidates that were eager to explain their more diverse and more specialised biological research, and they were attended by a higher percentage of bearded biologists, who were apparently more fascinated by plants and animals than by humans and their artefacts. They reminded me of the members of the society for amateur biologists, KNNV, which had local departments in nearly every municipality in the Netherlands. Since 1992, I had edited the quarterly of the KNNV department Zoetermeer, with Johan Vos, the municipal ecologist of Zoetermeer. This club magazine is filled with enthusiastic reports that concerned the new plant species that were found every season in this new town. It has become a detailed and amazing natural history of a new town, covering 20 years, counting more species per km^2 than many Dutch natural reserves with the same content of rarity.[b] The section ‘Town’ of the WLO publication, which was published by the KNNV, contained the contributions of other municipal ecologists, and scholars from Delft, including myself. The section ‘Infrastructure’ mainly contained the contributions related to civil engineering. Thus, our book contained very different scientific subcultures. This, however, is not only the case in ecology. Meeting the professionals in the PhD-committees that I chaired gave me the impression of small global villages, specialised experts that knew each other in a very familiar way (“Nice to see you!”), united by their own language and specialised scientific journals.

Design combining specialisms

Much of the content of the book on landscape ecology could be used for my lecture paper on urban technology. It answers the question of why my chair was named ‘Technical ecology’. For the students, however, this was only a minor part of a course, a train of wagons passing their rail-station as if it had no ending. They did not have enough time to realise that every wagon has different compartments as well. Therefore, the examination of the course had to start interrogating the students’ own designs published on their personal website. There they answered the questions “What did you do with Sun, with Wind, with Water…?” and so on; “What *could* you have done, knowing what you know now?” and “What are you going to do with this knowledge in your *next designs*?”. They *calculated* different

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[a] Jong;Dekker;Posthoorn(2007) *Landscape ecology in the Dutch context: nature, town and infrastructure* (Zeist) KNNV-uitgeverij

[b] See http://team.bk.tudelft.nl/Publications/KNNV.htm

aspects of their own designs, and I hope they became *aware* of the many ways their design can be judged by specialists in practice. I hope that they will not take these specialist's calculations and advice for granted. I hope they will be able to ask the right questions before they adapt their design into a traditional compromise. Though I was not involved in any studio in the last years of my teaching, the student's websites gave me a nice overview of their results.

Beijing

Some students requested me to become part of their graduation committee. They became true academic friends. Let me give one example. I cannot conclude much difference in the average quality of students from Europe and Asia, but there may be a difference in the extremes of disappointing or amazing students. According to the population, there are probably more exceptions escaping the statistic deviations in China than in the Netherlands. Xiaorong Zhang asked me to join her graduation committee for technical advice. She told me that Beijing suffers from heat in the summer, which causes many casualties. By replacing some neighbourhoods with parks, the government succeeded in reducing Beijing's urban heat island effect from +5 ◦C to +4 ◦C. Xiaorong wanted to make a design for urban renewal of an old authentic neighbourhood with narrow streets. What could be done that was better than relocating its inhabitants to the outskirts of the city, in favour of the wind? "I noticed that you have done wind tunnel experiments.", she said. "Yes, but that is a long time ago, and they are very expensive"."It does not matter, there are formulas now, in order to calculate the effects at a larger scale than buildings, and in order to compare different solutions." I was apparently not up-to date with my knowledge of wind modeling, and she sent me a French article with many formulas. The formulas and their complicated relationships requiried a lot of morphological data, which embarrassed me. I could not understand them without extensive study, but she mentioned them in her first graduation report, and had already drawn some preliminary conclusions. It impressed the other members of the committee, who did not have any understanding. They looked at me. I had to do something.

Fig. 252 The God of longevity

I mailed Xiaorong that she had to wait until I would have time to simulate the formulas in Excel during the Christmas Holidays. The first formula took me a day. Proudly, I mailed her the Excel file, and she answered the next morning: "Dear professor, you did an excellent job! What beautiful sliders and moving graphs you made! There is, however, something wrong in cell G30 and H5. I will look for a solution." I hastily restored my mistakes before she could send a solution. I mailed her the improved sheet and I started immediately to elaborate on the second formula, forgetting the time until Ellen, my wife, asked me for dinner. "It is our holiday!" … "Yes, yes." The story repeated 3 times, until I received a mail from Xiaorong with congratulations for the New Year: "Pff, that is complicated! I am in Rome now. As soon as I am back I will give you a reaction." I finally was on level with my student, and the results fit rather well with the experiments from 25 years earlier.

When she was back in Delft, she explained to me what I still had done wrong, by consulting 3 pages of written notes in Chinese characters. Some months later she graduated with a nice design, and a train of extensive social and physical evaluations, of which my graphs were only one wagon. The committee could not understand all the details, and they asked her if she had not *forgotten* something. “No”. The committee could not find something missing either. After the graduation, I received a very nice mail full of gratitude, which contained the picture of *Fig. 252*.

Paramaribo and Gui Yang

I do not like travelling, but my true academic friend Peter Luscuere, professor in Building Physics from our department of Building Technology, invited me to join a delegation of the Dutch engineering bureau Haskoning into Guy Yang, and I did. The project is elaborated on page 181 of this thesis, but my impression of China was not very different from my experience in Surinam. The young man stayed in Surinam for one year in military service. He was increasingly impressed by the tolerance between so many cultures (16 languages) in such a small population (a third of a million at the time). He was particularly impressed by the very different, but always hospitable tribes surviving in the magnificent tropical rainforest for centuries. The young man was *trained* to survive there for a period of only one week. In the capital Paramaribo, the main Synagogue is located next to the main Mosque. People were joking about each other and about us, but they remained living in a model peace. A Christian girl wanting to lose weight, simply joined the Ramandan of her friends. It seemed as if they expected everybody to be different, joyfully celebrating the similarities of any encounter. In the Netherlands we are trained to expect equality, depressed by differences appearing in any meeting. Of course, the Netherlands and both other countries are different, but the increasing similarities worried me more: the same cars, hotels, airports, pollution and the same indifference in regards to nature. The difference between scientific disciplines is larger.

Adapazarı and Delft

In the same way, I was seduced several times to go to Turkey by my closest true academic friend Ali Guney, a member of my small Chair. He asked me for advice concerning Adapazarı, the place where he was born. The Lord Mayor of Adapazarı had visited his mother somewhere in the mountains, where he had learned that Ali stayed for holiday. This was very surprising, because Ali was a persona non grata in Turkey, due to his political past and his convinced atheism. The Lord Mayor, beloved by his citizens, and consequently being in office for an exceptionally long period, was an Islamite and the most moderate and tolerant person I have met, except perhaps Ali himself. Ali had been his link to Delft and he visited our University, with his wife assisting him with her advice in the meeting with our Rector Jacob Fokkema. He left a deep impression on me. He requested us for advice concerning his municipality, which was hit by a serious earthquake in 1999. The project is elaborated on page 247 of this thesis. In Turkey, I recognised the contrast of Atatürk´s revolution and the Islamic Ottoman remains everywhere. For me, the combination of history, religion and culture were more tangible in Turkey than in the other countries. It is the country where Thales gave birth to mathematics, and to the Greek and Western way of scientific thinking.

A Chair of true academic friends

Ecology is not a core business in a Faculty of Architecture, and I never had the ambition to extend the number of Chair members. This spared me the trouble in times of shrinkage and it would spare my successor to cope with co-operators (s)he did not choose. The physical geographer Riet Moens accompanied my first steps as a professor. She pitied the magic box of the young man she had already known as her student. For a short period her colleague Ina Klaasen (occupying the Chair Regional Design until Hubert de Boer came) joined my Chair … and Riet’s critical remarks. As a strong fighter for empirical research in design, she was my best opponent stirring up the Chair with weekly debates, sharpening its arguments. After her departure, these debates continued, often in the open air, at the covered balcony of my room with a broad view on the campus and the old town of Delft, where William of

Orange fought for tolerance and for our independence. Egbert Stolk, an excellent graduate, joined the Chair and the debates as a PhD candidate, convincing me to employ Ali Guney, a Socratic and a very literate teacher. Ali introduced precedent analysis as a necessary application of cognitive science in design education, inspired by Alexander Tzonis. The weekly debates descended into the most fundamental epistemological questions. Egbert, observing a repetition of arguments, preferred to organise international conferences with internationally famous participants on complexity, self organisation and cognitive science, to write books and articles, to obtain commissions and funds. He convinced the department of Urbanism to invite Yuval Portugali, the well-known geographer from Tel Aviv, as a guest professor on self organisation and cognitive science in the city[a]. He brought all kinds of celebrities of complexity theory into the Faculty. I attacked them at his conference, organised by Egbert. Batty was amused, Haken did not agree ‘at all’ and Salingaros threatened me beforehand not to attack him, but I did not receive any counter-argument from this society of believers. Yuval made many converts in the department of Urbanism, but he became one of my true academic friends. He was more than anyone else amused by, and interested in my objections. Concerned about the fading interest for design and possibility-search, I was happy that landscape architect Martin van den Toorn had joined the chair. He moderated the debate referring to many examples of large Dutch design projects changing the face of the country though design (without any self organisation or cognitive science), proving his impressive knowledge of literature. PhD-candidate Olgu Caliskan, an excellent graduate of METU Ankara, appeared to be an authority on urban morphology before his doctorate. He was *asked* by publishers instead of searching for them. He attended the debates with a distance of sound scientific doubt. With him, the variety of opponents seemed to be sufficient to exercise my loud objections against the returning hypes of thirty years ago, so irrelevant for design. The many international external academic guests attending our debate through the years, were frightened by our noisy debates in the beginning, but they gradually understood this kind of friendship. Academic guests add more than managers can imagine in publishing and putting local fashions into perspective.

Systems theory and cybernetics

After the debates regarding empirical science and design with Ina and Riet, issues of complexity, self organisation and cognitive science dominated the debates with Egbert and Ali. This reminded me of the arguments of young man against systems theory. Systems theory already attempted to cope with the ‘complexity’ of an observed diversity and dynamics that you cannot conceive. Systems theory assumes, that you do not have to understand the object and its internal process, if you study it as a ‘black box’ with an external input and an output. It may be sufficient to *construct* a process with similar inputs and outputs. This is useful if the input is properly defined, but in living systems you often overlook inputs. For example, birds are disturbed by your observation. Unconscious inputs in humans change their behaviour in the laboratory or if you ask them to fill in a questionnaire. Moreover, you cannot bring them in extreme and unnatural conditions by creative experiments as physicists, chemists and biologists can do. Psychologists, sociologists and economists are restricted to historical and anthropological data and to small deviations from normal conditions by experiments. The inputs of humans cannot be controlled, because they select them on their own initiative. Cybernetics adds to systems theory the influence of the output upon the input by feed-back. If the output does not agree with some standards, then the input is regulated by feed-back. Measuring the deviations of the impact of canon balls compared to their target deliver correction data to the canon for the next shot. The problem is, that these targets or *standards* may change *in* the black box if there are hidden inputs (for example in humans and in their societies). The amount and the diversity of co-efficient inputs of humans may be inconceivable.

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[a] Portugali(2008) Self Organization And The City. **IN** Meyers Encyclopedia of Complexity and Systems Science —Entry 759 Springer

Selection by the selected

Our imagination is limited. You may receive ample 100MB/s (10TB/day) from your senses. The physical access into consciousness is much slower. Less than a *millionth* part of these impressions can become 'conscious' and even less can be expressed in an understandable language.[a] The rest is unconsciously used for physical reflexes or immediately forgotten. Which selector selects the conscious part of these numerous impressions? Which selector subsequently decides which part will be expressed in some language or stored into our selective memory (1-10 TB)? Which selector, then, destroys the 'useless' memories in order to keep space for new ones?

What you remember are *similarities* that may be useful in the expected rest of your life. From these similarities you reconstruct an other reality called 'imagination'. This imagination is the basis of your expectations, desires and fantasies about *possible* and impossible objects. Repeated observations in similar conditions may produce *suppositions*, but the conditions are never the same. These *suppositions* may select the 10B/s from the 100 000 000B/s we observe in order to get through into your consciousness. These *suppositions* are the selectors of your consciousness, expressions and memory. They are, however, themselves the result of earlier selections. They are the result of a circular process of *selection by the selected*. The first supposition thus cannot be based on *similarity* if there are no earlier impressions to compare with. There must be a supposition prior to similarity. In this thesis I assume that it is *difference*. Similarity, then, is a special kind of difference, but it is still a difference. Everything differs. Any difference, however, is different from any other difference. If you cannot observe or imagine the difference, you *name* them 'similar', 'comparable' or even 'equal'. This 'equality', however is a supposition that cannot hold after any second observation, because this observation must be a different observation to be a second one. Even *counting* different objects assumes an equality between them that cannot hold if they are different. Difference is the language of the senses, similarity is the language of common sense. We call our set of suppositions 'knowledge' if it can be expressed in words, and if it is repeatedly tested by different persons as 'true' or 'probable'. In this thesis I have used the word 'knowledge' or 'cognition' with great reservations. Knowledge must always be questioned, and it may hamper the possibilities of diversity and of design.

Cognitive science

In a two-dimensional drawing, contradictions remain possible, as any designer knows. This designer's 'knowledge' cannot be ex*plain*ed in sentences or linear logic, but you can communicate it in drawings. If you accept proper drawings as scientific documents, it is no 'tacit knowledge'[b]. This 'knowledge' cannot be explained by analogies of computing machines. Why distinguishing the computer programming terms as 'declarative knowledge' for the variables, 'procedural knowledge' for the operations, and then add some 'tacit knowledge' as a kind of mystical human rest-category? Any 'knowledge' is a set of suppositions that direct and select your observations. These suppositions are called 'true' or 'probable' if they are tested, but you must stay questioning the suppositions of testing itself. The presupposed categories, variables and words of any test chain your imagination. Where are the modes of desirability and *possibility*? There are many more variables conditioning the input and the resulting output. There are many agents at another level of scale than what we observe as a unity, a system. But, that was already known and studied for decades in ecology. Most of its agents (species) are still undiscovered and their operation is still unknown. We still cannot cope with the irritating *diversity* of nature; that is the question. I cannot cope with it either, but I am at least aware of my limits. The level of scale is a crucial limit of observation and imagination. At every level of scale they are limited by two black boxes: one inside its grain of resolution and one outside its frame. This usage of the word 'frame' is substantially different from its usage in Cognitive science (activated suppositions).

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[a] Silbernagel;Depopoulos;Gay;Rothenburger(2001) *Atlas van de fysiologie* (Baarn) SESAM
[b] Polanyi(1966) *The tacit dimension* (New York) Doubleday

Complexity-theory and self-organisation

I do not require a concept of complexity to study different diversities at different levels of scale. Of course, Ashby[a] and Minsky[b] did a nice job, but every thirty years a similar 'new kind of science'[c], seems to result in a deterministic hype that limits the human power of imagination and design by the analogy of machines. I do not know much about Complexity theory, but I cannot escape the impression that it is a successor of systems theory with even less concern about the input. It, then, seems to be sufficient to construct a procedure with a limited set of inputs and operators in order to obtain outputs that seem 'similar' to what you observe. Complexity theory then can be named more appropriately as Simplicity theory. My moderate experience with computer programming taught me that many repeating feed-backs in a very simple program may result in a chaotic process and a sudden appearance of fascinating regularities in the output, but these regularities or *order* are not the same as *organisation*. The emergence of regular patterns in a random vector field appearing on computer screens is incomparable with an operational exchange between diversifying *organisms* selecting each other by ecological evolution, or with an *organisation* through differentiating cells and *organs* in an *organism*. The resulting *form* may be similar, but the scale-dependent structure and –operation are substantially different. You should make things as simple as possible, but not simpler.[d] The confusion of morphological *order* and chemical, biological and economic *organisation* reminded me of Ashby, McLoughlin[e], Odum[f], Prigogine[g], already written off by the young man as a religion of cheap mathematical analogies and generalisations. Smith's 'invisible hand' creates prosperity *and* disasters at different levels of scale. Chaos appears as order at another level of scale. If you are not aware of this scale paradox, scale falsification will disturb your senses, sense and sentences.

Dubious suppositions of classical empirical research

The debates regarding empirical science and design with Ina and Riet resulted in the publication with Theo of 'Ways to study and research urban, architectural and technical design'. This increased my appreciation of empirical research, but it did not solve the question already bothering the young man. Empirical research emphasises the input, but its attempt to *generalise* by *reduction* is a paradox I could not accept from a viewpoint of spatial design. Distinguishing a population for statistical analysis (a set) supposes already an equality beforehand of some 'properties' between its elements neglecting the differences. The term 'property' is problematic in the mode of possibility. The collection of data about a population defined by some properties (the input of the research) is the weakest point in statistical analysis, because any data set already assumes their comparability in one respect (the criterion of the set and its resulting variable). If the elements of the set are different in other respects, you will obtain a 'statistics on heterogeneous sets'. I cannot accept its results as completely reliable, because the conditions of the elements are not equal. A set of people (or any other species, any other ecological community) is heterogeneous by its still inconceavable biological diversity and so are their contexts. Statistical operations on a 'category' of people then cannot be valid by definition; their generalisation cannot be reliable in every context.

[a] Ashby(1962) *Principles of the self-organizing system* **IN** Foerster, H.V.; G. W. Zopf, J. Principles of Self-Organization: Transactions of the University of Illinois Symposium (London) Pergamon Press p255-278
[b] Minsky(1985) *The Society of Mind* (New York, 1988) Simon & Schuster Paperbacks
[c] Wolfram(2002) *A new kind of science* (Champaign) Wolfram media
[d] Attributed to Einstein. See, however, http://quoteinvestigator.com/2011/05/13/einstein-simple/
[e] McLoughlin(1969) *Urban and regional planning. A Systems Approach* (Bristol) Western Printing Services Ltd.
[f] Odum(1971) *Fundamentals of ecology* (Philadelphia/London/Toronto) W.B. Saunders Co.
[g] Prigogine;Stengers(1979) *La nouvelle alliance. Métamorphose de science* (Parijs) Gallimard

Pragmatism in a limited context

However, generalisations may be *useful* in particular niches of application. They are particularly useful for marketing, because the average sells best. Statistical analysis interprets the deviations from a supposed average as different degrees of probability, but a heterogeneous set has no average. The consequence is, that the improbable exceptions are neglected. Exceptions are not important for marketing a product, but they are crucial in evolution and design and sometimes desastrous in statistical practice. For example, if you select a set of people with apparently equal diseases, and you give half of them a chemical substance and half of them a placebo, then you may conclude *on the average* a positive effect. The diverse and rare negative side effects, however, may be as different as the heterogeneous set you tested. If so, then each of these side effects is not significant enough to be mentioned in the leaflet, and they cannot be proven to be related to the medicine afterwards by statistical means. That is profitable, because then you can develop medicines for any of these rare side effects without blaming your previous medicine as being their cause. You create your clients. This is the way linear problem solving may cause more problems. Spatial design should solve problems with an awareness of the side effects. It is the power of drawing to show side effects perpendicular to any line of reasoning.

Generating instead of generalising diversity

Generalisation reduces diversity. Reducing diversity reduces possibilities and freedom of choice for future generations. Diversification *generates* possibilities, but how to create diversity? Creativity requires questioning common generalisations, suppositions. I do not pretend to be very creative, but I questioned some common suppositions (e.g. de concept of 'equality') in order to obtain more space for imagining possibilities. Questioning them, however, may threaten interest-based suppositions. I obeyed my parents, warning: "You should not generalise". They payed, however, for the education teaching me the many ways to generalise called Science or Humanities. Doubting their generalisations is easier without a study dept to be paid by selling them. The message "You *cannot* generalise" is difficult to sell, and it undermines your living as a scholar. In the rare places, quietly separated from the dynamics of globalisation, rare plants may grow. My Chair survived in the shade of an international Faculty. It hided from the acoustic feed-back of fashion and fame. It was a place where doubt and debate florished in plain terms. The names I mentioned here, are not intended as the context of a personal biography. They are primarily intended to label the phases of a development clarifying the origins of this thesis. The persons behind them, however, were also true academic friends. I thank them for their objections, not for their approval. They changed and sharpened my arguments. I profited from their difference. We had not much more in common than loving doubt and debate. Some of them, however, did more to be grateful for. They sustained my efforts even if they disagreed, as a midwife does while it is not her child. My wife Ellen was the sacrificing midwife of this extramarital thesis. And my famous promotores Maurits and Dirk? Did they agree? I do not know, and I do not have to know. They took their precious time in order to read what I wrote. They judged my arguments, they skilfully advised to skip and to add. The least and most appropiate thing I can do in return is to publish my sincere gratitude in the end of this afterword.

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List of figures

List of key words

See page 274 for the use of syntactic key words (with brackets).
Italics refers to pictures. **Fat** refers to authors.
Variables begin with a Capital.

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Propositions attached to
Jong, Taeke M. de(2012)Diversifying environments through design(Delft)TUD PhD thesis

In this thesis:
1. A linear language cannot cover space, its diversity or possibilities. (p281)
2. The meaning of words change per level of scale. (p283)
3. Educating design must start by drawing and modelling. (p287)
4. Difference is the language of the senses; similarity is the language of common sense.
5. Space enables the realisation of contradictions. (p287)
6. Mono-functional environments postpone the satisfaction. (p286)
7. Culture is a set of shared suppositions.
8. Creativity requires skipping at least one commonly shared supposition.
9. Images precede language. Language consists of routes in the image.
10. Separating functions saves time and cost space.
    Combining functions saves space and cost time.

Beyond this thesis:
11. Forms in-form; words re-mind.
12. Science is a design, not the other way around.
13. Geography and history limit imagination. The task of a designer it to make them.
14. If probability implies a causal sequence, then possibility implies a conditional sequence.
15. Arguments in science and the humanities score less than compliments.
16. Truth has no copyrights and lies should not be paid.
17. Commercial journals are the graveyard of science and the humanities.

These propositions are regarded as opposable and defendable, and have been approved as such by the supervisors Prof. Ir. C.M. De Hoog and Prof. Ir. D.F. Sijmons.

Stellingen bij

Jong, Taeke M. de(2012)Diversifying environments through design(Delft)TUD PhD thesis

In dit proefschrift:

1. Een lineaire taal kan de ruimte in zijn verscheidenheid en mogelijkheden niet dekken. (p281)
2. De betekenis van woorden verandert per schaalniveau. (p238)
3. Ontwerponderwijs moet beginnen met tekenen en modellen maken. (p287)
4. Verschil is de taal van de zintuigen; gelijkheid is de taal van het verstand.
5. Ruimte maakt de realisatie van tegenstrijdigheden mogelijk. (p287)
6. Mono-functionele omgevingen stellen de voldoening uit. (p286)
7. Cultuur is een verzameling gedeelde vooronderstellingen.
8. Creativiteit vergt het weglaten van tenminste één algemeen gedeelde vooronderstelling.
9. Beelden gaan vooraf aan taal. Taal bestaat uit routes in de voorstelling.
10. Functiescheiding spaart tijd en kost ruimte. Functiecombinatie spaart ruimte en kost tijd.

Buiten dit proefschrift:

11. Vormen in-formeren; woorden her-inneren.
12. Wetenschap is een ontwerp, niet andersom.
13. Aardrijkskunde en geschiedenis beperken het voorstellingsvermogen.
    De taak van een ontwerper is ze te maken.
14. Als waarschijnlijkheid een causale volgorde impliceert,
    dan impliceert mogelijkheid een voorwaardelijke volgorde.
15. Argumenten scoren in de wetenschap minder dan complimenten.
16. De waarheid heeft geen kopierechten en leugens verdienen ze niet.
17. Commerciële tijdschriften zijn de begraafplaats van wetenschap.

Deze stellingen worden opponeerbaar en verdedigbaar geacht en zijn als zodanig goedgekeurd door de promotoren Prof. Ir. C.M. De Hoog en Prof. Ir. D.F. Sijmons

Delft, Zoetermeer 2012 ISBN 978-94-6203-172-2