

# 6 Living, human density and environment

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## 6.1 Adaptation and Accommodation

### 6.1.1 Human population

#### Adaptation and accommodation

This chapter deals with the adaptation of the human species to its habitat (adaptation), and the adjustment of the human habitat to the species (accommodation, technique).

The unmatched growth of human population is due to its faculty of toolmaking and consequently, its accommodating capacity. That accommodating capacity happens to be the object of architecture and urban design.

#### Architecture and urban design as a part of ecology

So, the chapter approaches architecture and urban design as human ecology, a part of aut-ecology<sup>273</sup>, necessary to understand the distribution and abundance of this particular species and its remarkable artefacts on Global, European, national, regional and local levels. Syn-ecologically it is interesting to see how this species recently developed into a plague, ousting other species and changing the environment (environmental ecology). From a viewpoint of systems ecology its potential to survive on any level of scale in space and time could be studied, taking global resources into account. Cybernetic ecology could prove helpful for design and chaos ecology for management.

#### History as a laboratory

However, this chapter starts with a historical approach, because history is a kind of laboratory unveiling suppositions of our existence we are inclined to forget.

#### Anthropogenesis

For millions of years, human characteristics have been tuned to the natural environment in which people had to survive (adaptation). Therefore, it is useful to acquaint oneself with this 'reference' environment as such, and, now and then, to allow this nature to be the tutor of architectural (and mechanical engineering) forms. Even in the most advanced studies into the development of autonomous robots, the mechanics of insects are attentively observed. Also in the other development that is thought to be important for the future — biotechnology — nature is often 'the tutor of art' ('Natura Artis Magistra').

#### Human habitat

In the history of human origins (anthropogenesis)<sup>a</sup>, human adaptation and environmental determination have played a major role. Different human-like animals such as *australopithecus* developed and later became extinct. Approximately 2 million years ago, due to climatic and environmental changes in Africa, *homo habilis* with larger brains than its predecessors exchanged a forest habitat for savanna starting to eat meat.<sup>274</sup> This species' apparent use of tools has often served as a criterium to demarcate humanity: the capacity to oversee a series of acts of which only the first (e.g. the making of tools) can be carried out immediately.<sup>275</sup> The use of language or fire as tools both suppose such an ability. Subsequently, *homo erectus* developed with many variants. Thirty thousand years ago only two species remained, *homo neandertaliensis* and *homo sapiens*. The neandertalers existed at least 500 000 years, but became extinct, leaving *homo sapiens* with a common ancestor in Africa approximately 150 000 years ago as the sole human survivor.

#### Arboreal pre-adaptations?

The origin of the human race, preceding *homo habilis*, should have produced a number of ergonomically interesting 'aboreal pre-adaptations' (adaptations to the former forest environment), such as the ability to grasp with the hands, stereoscopic vision, upright posture, the production of a limited number of offspring at each pregnancy, a lengthy up-bringing of the offspring, etc.<sup>276</sup> The tropical rain forest is then by no means as frightening as it is made out to be. It is a fantastic experience to cut a path for oneself through this twilight environment: it feels as though one is returning

<sup>a</sup> De opvattingen over de antropogenese zijn jaar in jaar uit sterk in beweging. De hier uitéengezette opvatting is ontleend aan het wat oudere maar voor ons doel vrij volledige boek van Harrison, G. A., J. S. Weiner, et al. (1964) *Human Biology* (Oxford) The Clarendon Press/Harrison, G. A., J. S. Weiner, et al. (1970) *Biologie van de mens* (Utrecht/Antwerpen) Het Spectrum N.V..

home after 6 million years. All the senses are stimulated in a changing, yet balanced, way. One can seldom see further than 100 metres ahead and is constantly obliged to focus the eyes on objects both nearby and further away. Moreover, it is an environment similar to a Gothic cathedral: full of vertical light-seeking pilasters, in which, occasionally, the sun festively forces its way to the bottom. This demands continuous attentiveness, but, on the other hand, the senses seldom become overloaded.<sup>277</sup>

### Savanna adaptations?

The 20<sup>th</sup> century witnessed the clearance of the last primitive forest peoples and their culture and habitat. Nevertheless, a cultural-ecological study of these communities that are so closely linked with our reference environment could be of importance for future urban design.

The transition from forest dwelling to life on the flat savanna lands must have made the eyes lazy, but the hands and the head more diligent. Particularly in between these environments people seek cover and build their own protective shelters.

## 6.1.2 Habitat, density and economy

With the help of technical resources, the human species nowadays can maintain and organise itself to suit its own wishes in every biotope (accommodation). In general, such accommodation results in pioneer, grassland and brushwood vegetations. Sometimes, mankind changes the dominance relationships in the landscape to such an extent that, in places, the old situation remains protected (nature conservation) or new successions are allowed to come into being (nature development).

### Habitat and density

Different populations live in different densities (Fig. 825)<sup>278</sup>.

HABITAT	% total land area on earth	% total world population	inhabitants per km <sup>2</sup>
Dry lands and deserts	18	4	10
Tropical forest/ shrub crops	15	28	60
Grassland areas	21	12	20
Semi-forested areas	7	39	190
Mediterranean shrub overgrowth	1	4	130
Temperate to cold area	10	1	3
Arctic/tundra area	16	<1	1
Living area in the mountains	12	12	30

Fig. 825 Population densities in different habitats 1970<sup>a</sup>

<sup>a</sup> Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

### Habitat and economy

Each habitat has resulted in different forms of economic household management (Fig. 826). In mediterranean scrub and tropical grasslands (savannahs) all types of economy have been found.<sup>279</sup>

	Food-gatherers	Hunters	Pastorales	Nomads	Simple cultivators	Advanced cultivators
Equatorial forests	Siamang	Pygmies, Melanesians			Amazone, Nw.-Guinea	Indonesia, Java
Tropical forest and scrub	Grand Chaco indians	the Bantu	the Bemba		Indo-Dravidians, South Americans	Bantus
Tropical grasslands (savannahs)	Australoids	Hadza (East Africa)	Nilotes		North American Indians	Hamites
Drylands and deserts	Bushmen and Australians			Bedouins, Tuaregs	Oasis dwellers	Oases (riverine)
Temperate forests	Australians, Mesolithic Europeans	Tasmanians, Predmost	Iron Age Europeans		Chinese	Peasant Chinese
Mediterranean scrub	Strand lopers	Californian Indians	Balkans	Berbers	Neolithic Iron Age, Maori	Medieval Europe
Temperate Grasslands	Paleolithic Europeans		Mongols	<i>boerjaten</i> , mongols	Siouan Indians	Pawnee indians
Boreal	Fuegians	Samoyeds		Lapps		
<b>TUNDRA</b>		Eskimos		Lapps		

Fig. 826 Habitats, economies and cultures<sup>a</sup>

From this it appears that there is no simple relation between habitat and household management, as believed by physical determinists at the end of the last century.(Claval, 1976).

POPULATION	km <sup>2</sup> per head	heads per km <sup>2</sup>	for 100 people	
			km radius	nominally
Food gatherers				
Upper Palaeolithic (Eng.)	500	0,002	126	100
Australian aborigines	60	0,017	44	30
Tierra del Fuego islanders	20	0,05	25	30
Andamen Islanders	1	1	6	10
Developed hunters/fishermen				
Eskimos and Indians	500	0,002	126	100
Eskimos (Alaska)	80	0,0125	50	30
Mesolithic man (Eng.)	25	0,04	28	30
Pampas Indians	5	0,2	13	10
British Columbians	0,1	10	2	3
Arable farmers and nomads				
Neolithic man (Eng.)	1	1	5,6	10
Pastoralists and nomads	0,25	4	2,8	3
	0,03	33	1,0	1
Iron Age man (Eng.)	0,25	4	2,8	3
Middle Ages (Eng.)	0,05	20	1,3	1
Middle Age man	0,02	50	0,8	1
Swidden farmers	0,001	1000	0,2	0,1

Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

Fig. 827 Economies and population density

<sup>a</sup> Harrison, Weiner et al. (1964, 1977 p 398) Harrison, Weiner et al. (1970)

### Density and economy

However, there is some relation between household management and population density (Fig. 827)<sup>280</sup>. In the last two columns, the areas are translated into the radius of a circle with the same or almost the same area for a group of 100 people<sup>281</sup>

The same approximated sizes will play an important role in comparing different urbanising models.

### From hunting into agriculture

The transition from hunting to agriculture has had enormous societal consequences.

In the village Beidha, in Jordan, the floor plan of dwellings changed from round to square during the 500 years from 7000 BC. This reflects a probable social development towards sedentary living with more task division and functional differentiation of the built environment (Fig. 828).<sup>282</sup>

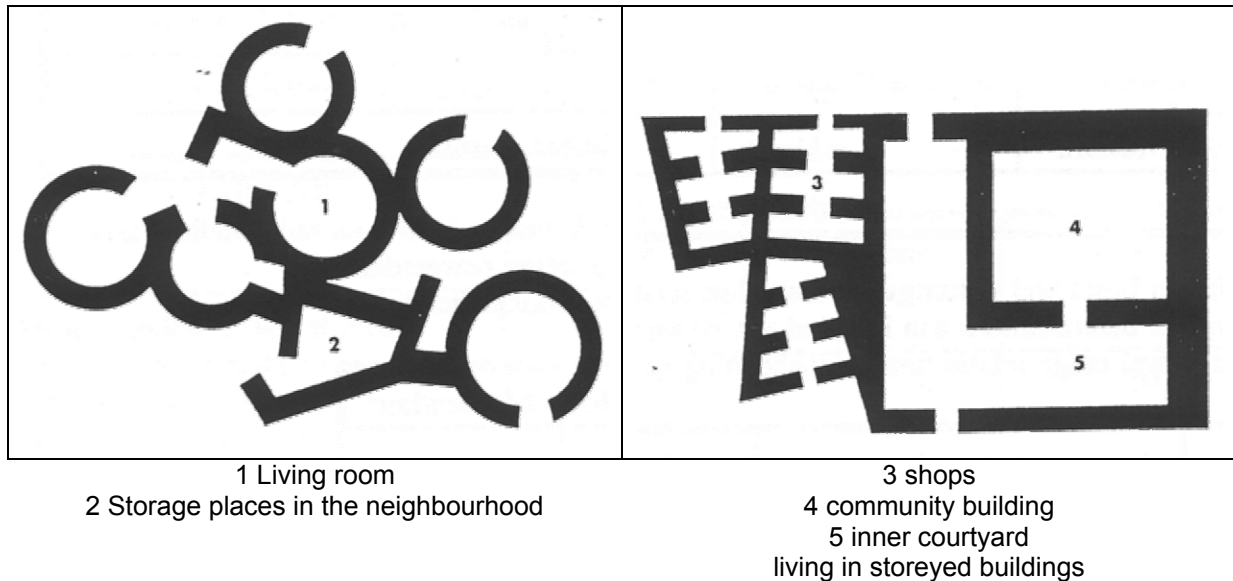


Fig. 828 Historical floor plans of dwellings that reflect the transition from hunting to agriculture<sup>a</sup>

## 6.1.3 Population growth

### Agriculture

If an animal or plant species gains dominance in a new habitat, then, initially, the population of these species can increase unhindered, but sooner or later it comes up against boundaries in the carrying capacity of the environment (in terms of Opschoor and Weterings (1994) and Koten-Hertogs, Beckers-de Bruyn et al. (1995) environmental utilisation space (milieugebruiksruimte), or (in the case of human beings) boundaries, which they themselves fix, within the existing biocoenosis (ecological community). If we couple the beginning of mankind with the use of tools, then the species is approximately 1 million years old. Agriculture (the Neolithic revolution)<sup>283</sup> was invented 10,000 years ago (1% of 1 million!). By means of agriculture, the species was able to enlarge, single-handedly, the carrying capacity of the environment and thereby to increase its population according to from approximately 4 million to 200 million by the height of the Roman Empire in Europe and the Han Dynasty in China.

### Overcropping and agricultural innovations

Round about the beginning of the Christian era this growth appeared to have slackened off, but, in the last 1000 years, growth has occurred again, which, as yet, appears to be exponential (see Fig. 829).

The slowing down of growth around the beginning of the era can be explained by the fact that all available land at that time suitable for agriculture was in use<sup>284</sup>. Erosion occurred due to overcropping, forcing some human communities to leave their homelands, and tribal migrations began to take place. Because of the limitations of agricultural land, people learned to be more careful with the soil by

<sup>a</sup> Leonard (1974)

implementing two- or three-year rotations, by applying fertilizers (nitrate cycle), by improving the plough and the storage (of the produce), etc<sup>285</sup>. After the Neolithic Revolution, the next big revolution came with the mastery of inanimate energy (Industrial Revolution beautifully described by Cipolla, 1970). Each technological revolution created the conditions for far-reaching economic, demographic, cultural and political revolutions and these, in turn, had enormous ecological consequences. Technical, agrarian and hygiene innovations can counteract the original environmental limitations and allow unlimited population growth for a time. Jong and Priemus (2002) discuss these and other approaches.

### Medieval fluctuations

Fig. 829 shows that in Europe, during the Middle Ages, significant population fluctuations occurred partly because of erosion and starvation, and partly because of (pest) epidemics.

The new exponential growth has mainly taken place after the Middle Ages, after technological developments had made their influence felt in the fields of agriculture, trade and hygiene.

War and illness, such as the enormous pest epidemic around 1300 A.D. interferes with population dynamics in a similar way to the activities of predators in a population of their prey<sup>286</sup>.

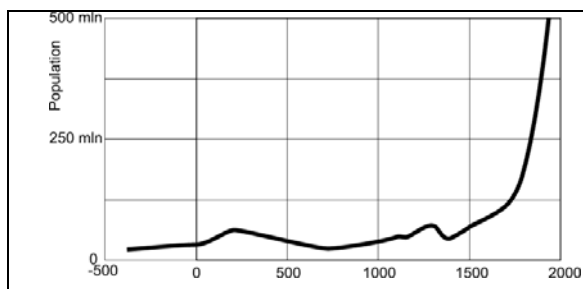


Fig. 829 The supposed developments in population numbers in Europe<sup>a</sup>

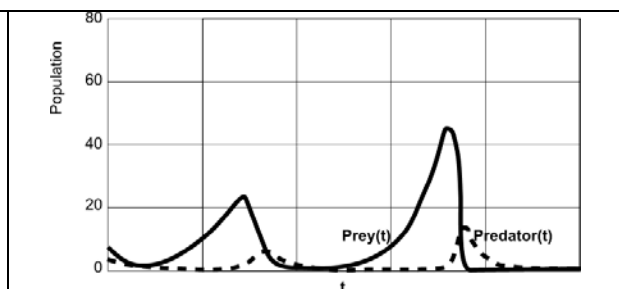


Fig. 830 Predator and prey according to Lotka-Volterra<sup>b</sup>

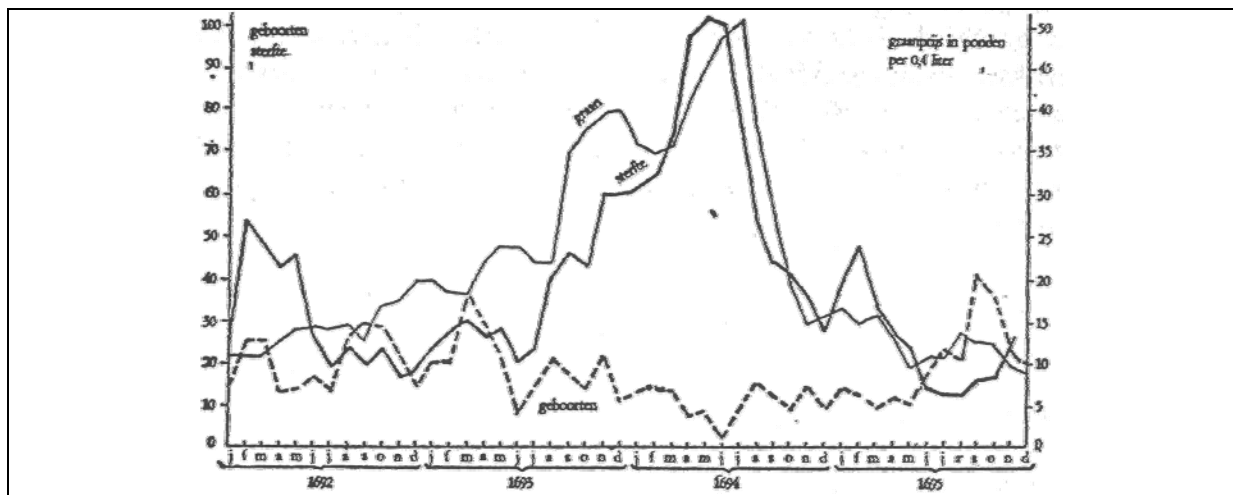


Fig. 831 Demographic crisis in Meulan, near Paris 1693-1694<sup>c</sup>

### Hunger

Historically, hunger is recognisable by the number of deaths, and is often related to the staple food. Increases in the price of grain are generally followed by more cases of death. Then, once the crisis periods have ended, the numbers of births increase again. This relationship is not only evident in history, but is still actual today, and will become more evident as the current world population develops<sup>287</sup>.

<sup>a</sup> Schlicher van Bath (1960)

<sup>b</sup> Jong and Priemus (2002)

<sup>c</sup> Lachiver (1964)

### Unlimited and limited growth

If there was no immigration or emigration, and the death rate remained constant, then population growth would be completely dependent on the number of children born. If the number of children  $k$  born to each individual was 1, then the population would remain constant, if  $k < 1$  then the population would decrease, if  $k > 1$ , then it would increase. The total population  $y$  of parents  $y_0$  and children  $ky_0$  is then  $y_0 + ky_0$  (Fig. 832).

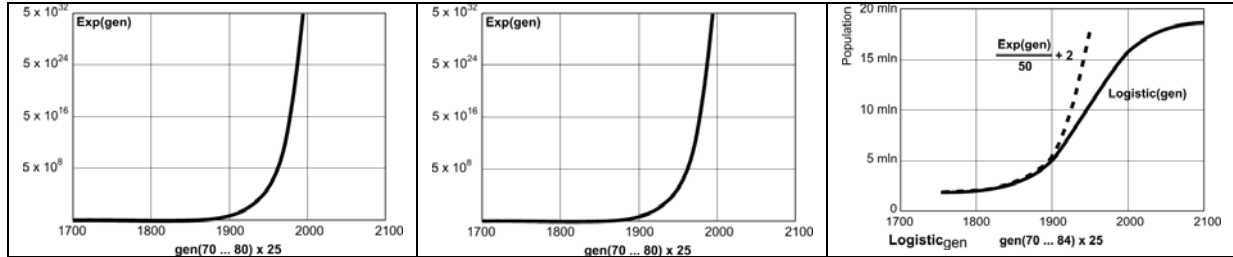


Fig. 832 Unlimited growth

Fig. 833 Adapted by parameter

Fig. 834 Limited growth because of carrying capacity

### Demography

Where death rates vary per generation, there is also a variation in birth rates. To contain these variations within one model, it is no longer sufficient to use a time-segment approach. Instead, one has to examine the population per cohort (Fig. 835)<sup>288</sup>. The branch of science that concerns itself with these activities is called demography.

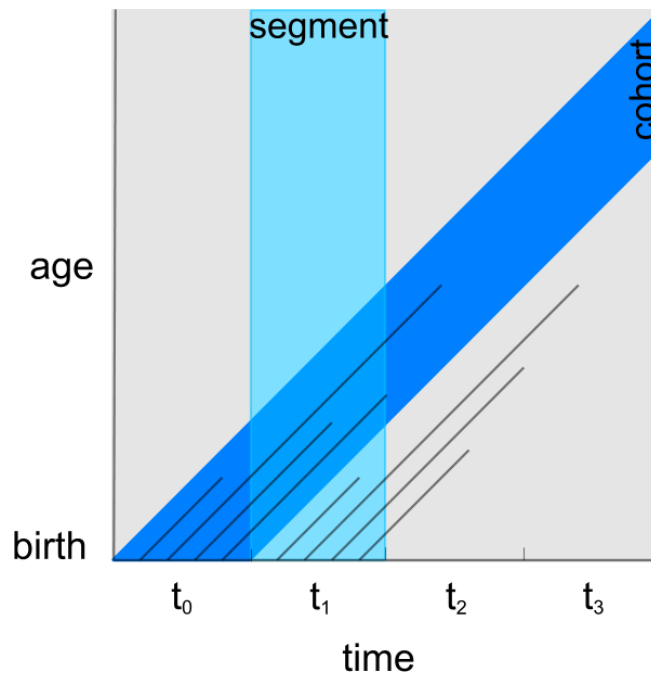


Fig. 835 Population in a certain period and per generation (cohort)<sup>a</sup>

Growth that is limited by the usable area of environment, or the carrying capacity of the ecosystem, is represented by a logistic curve (Fig. 834). Should we, for the time being, interpret the future of our population as one of unlimited or of limited growth?<sup>289</sup> Many people like Meadows, Meadows et al. (1992) think or hope, in view of limited raw materials, that growth will be limited. The logistic curve works beautifully for fruit flies, but when applied to the population of the United States, based on the demographic statistics from 1790 to 1910, reality proved this mathematical approach to be incorrect after 1950: growth is still exponential.

<sup>a</sup> Pianka (1994) citing Begon and Mortimer citing Skellam



### Technology

From technical history, we have learnt how a succession of technological innovations, in its totality (the 'envelope curve') can be reinterpreted as exponential growth (Fig. 836).<sup>290</sup>

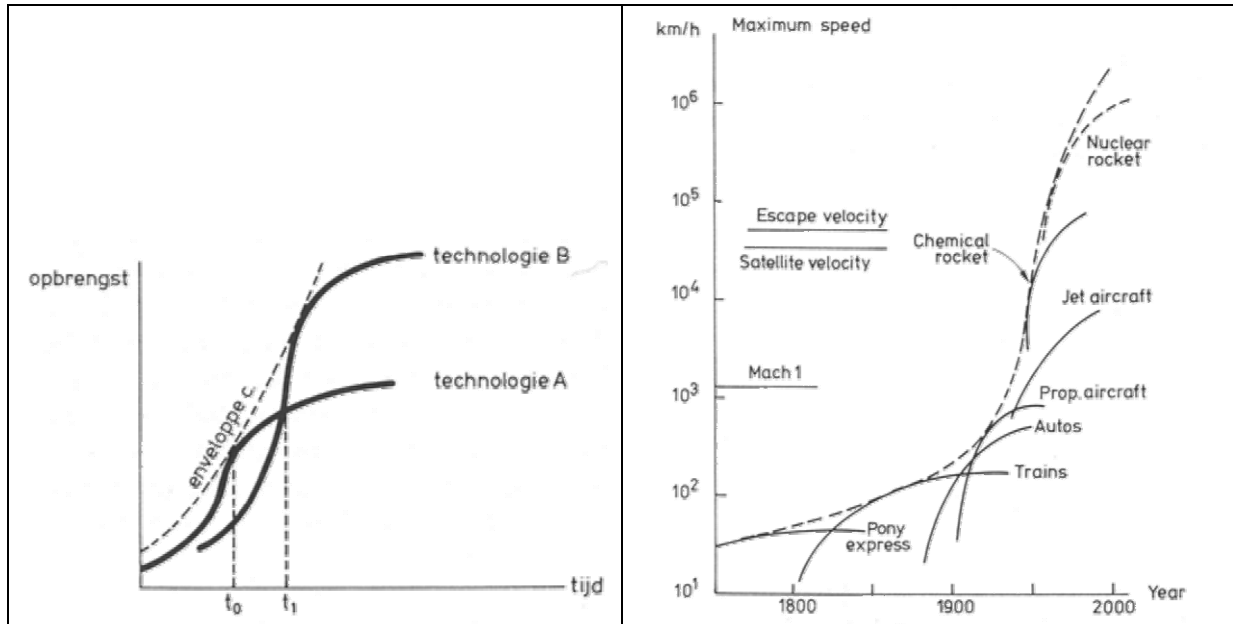


Fig. 836 The envelope curve and an example for transport technology<sup>a</sup>

### Chaotic growth

Fig. 837, and the following figures, illustrate a reflexive chaos function  $chaos_{i+1} := a \cdot chaos_i - a \cdot chaos_i^2$  for example with  $chaos_0 := 0.0016$  and  $i := 0 \dots 15$  that looks similar to a logistic curve on  $a=2$ , but which shows chaotic shifts on higher values of the parameter  $a$ <sup>291</sup>.

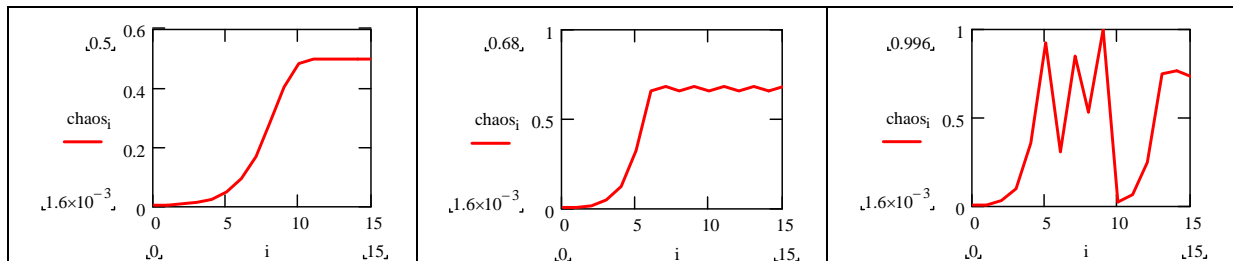


Fig. 837 Chaos using parameter  $a = 2$

Fig. 838 Chaos using parameter  $a = 3$

Fig. 839 Chaos using parameter  $a = 4^b$

### Limits to growth

Death has been largely and lastingly restricted by improved food, hygiene and medical science to older age groups, although not everywhere to the same extent. The most important variable factor that determines world population growth is the fertility or reproduction factor. Worldwide, of course, immigration and emigration play no role at all. The big question is: When will the current exponential-like growth in population level off again? The Earth is still able to feed a multiple of the current world population, but the distribution is so uneven that an unacceptably large proportion of this population is starving and dying. In time, not only will distribution be a problem, but the total amount of food will become insufficient.

At the same time, during the last 25 years, erosion has made 10% of the agricultural land unusable. Rising world temperatures will intensify this process by causing more deserts to form.

<sup>a</sup> Ayres R.U. (1965) en Jantsch E. (1967), cited by Doorn and Vught (1978)

<sup>b</sup> See also Jong and Priemus (2002)

## Changing predictions

According to CBS calculations (see Fig. 840), the Netherlands can expect population numbers to flatten off after 2030.<sup>292 a</sup> In 2002 a maximum of 18 million was expected, in 2006 a maximum of 17 million, declining after 2040.

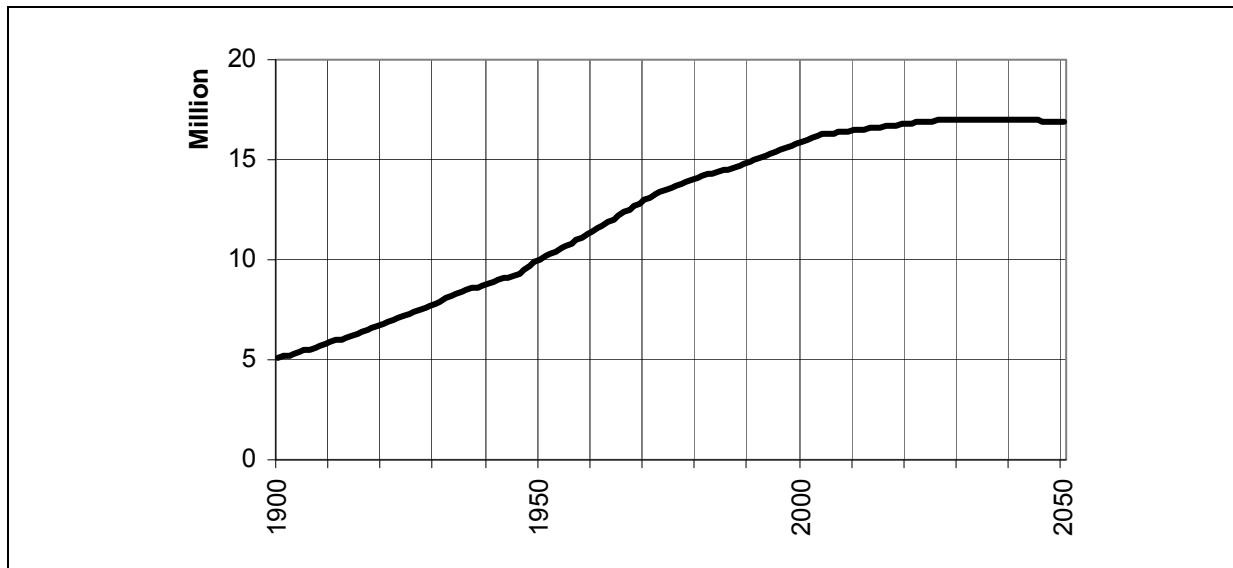


Fig. 840 The CBS population prognosis for the Netherlands, 2006

This development is expected in most Western countries, due to the decreasing number of births. Elsewhere in the world, so long as children are seen as the only form of health and pension insurance, this flattening off of numbers is not expected. The ecological crisis can then largely be seen to be linked with development problematics.

	infanticide	abortion	restricting coitus
Food gatherers and hunters			
Australian tribes (the Aborigine)	+	+	-
Tasmania	+	+	-
the Bushmen	+	-	-
Indians	+	+	+
Eskimos	+	+	-
Arable farmers			
Indians	+	+	+
Africa	+	+	+
Oceania	+	+	+
+ = number of confirmed cases    - = no reported cases			

Fig. 841 Methods of restricting the population used by 'primitive' peoples<sup>b</sup>

## Contraception

One of the most harrowing Western influences is that, so long as the mother breast-feeds her child and carries it with her, natural contraception is broken off. If the mother stops feeding her child for just one day, then she immediately becomes fertile again. A mother can feed her child for more than three years, but the Western example of laying a child in a cot and feeding it with a bottle has gained a higher status. The result is that a woman can become pregnant every nine months.

<sup>a</sup> <http://www.cbs.nl>

<sup>b</sup> Harrison, Weiner et al. (1964); Harrison, Weiner et al. (1970)

Western influence has not only brought about higher fertility in the Third World, but also a harrowing neglect of children still in their first phase of life. Every time a new child is born to its parents: the youngest child always receives the most attention. Contraceptive devices are used by almost all 'primitive' peoples<sup>293</sup>.

### Medieval population reduction

In the Middle Ages, hard measures were taken to reduce the population. If an area of land became over-used, at the very least or mildest, people were forced to move to marginal land. The history of marginal small-holders, tinkers, bandits, in short 'the destitute' ("ellendigen", "uitlandigen" exactly meaning: 'those who have been turned off the land') has never been written. The army, the cloister and the celibate can be seen as forms of contraception in the Middle Ages.

In this way, one can also explain how social norms in a farming community can be tightened (traditional costume!). People who were unable to live by such high norms were 'excommunicated'. The exaggerated norms were used as 'a stick to beat the dog'. Up to as late as the 20<sup>th</sup> century, in Staphorst, the black sheep was actually forced into a cart and driven out of the village.

## 6.1.4 The urban environment

### Industrial revolution

The biggest mass migration ever was (and is) the movement from the country-side to the towns that resulted from the Industrial Revolution<sup>294</sup>. The spatial and social consequences of that process are summarised under the term 'urbanisation'.

A progressive division between production, exchange and consumption (working, transport, living and recreation) has taken place, both in space and time, so that monofunctional spaces and interfunctional activities (activities that are only useful within a series of activities) have come into existence. This division of functions does not only take place between households, but also on the level of the individual households themselves. For everyone, there is a separate time for living, working and enjoying leisure. The household is losing its traditional functions such as providing training, religion, assurance and by that it is losing size and coherence.<sup>295</sup>

### The use of time

How people spend their time gives a good indication of their daily lives and their use of space. Less and less time is needed to sustain life. Apes and people who currently live at subsistence level, and many households in the past, need(ed) to spend 40% of their time on that. Nowadays, by dividing tasks, we only spend approximately 8% of our time earning our daily bread, if one includes children, pensioners and others exempt from paid employment.

### Misfit

The fact, that communities whose main activities are unrelated to the environment to which they have become attuned in the course of their history, can lead to long-term, unbalanced, over- (or under) stress in the organism. Insufficient adaptation to this stress causes lop-sided development. For example, one can wonder why hardly anyone has perfect teeth or cannot see clearly, without artificial aids, by his fiftieth birthday.

### Crowding and disease

Living in closer proximity to others increases the risks of spreading infectious diseases, anonymity, loss of social control and new forms of criminality, even though according to Freedman (1975) the psychic effects appear not to be too adverse. A new biological tendency has come into existence that causes isolation, strongly polarising life into public and private spaces as Bahrdt (1957) described<sup>296</sup>. Accommodating to abnormal climates also sets physical demands on this isolation. The resulting 'inner environments' not only become a new habitat for humans, but also for birds, rats, mice, fleas, mites, fungi, bacteria, pets and house plants. Asthma, as the third largest cause of death after cancer, heart and vascular disease, is a problem mainly in temperate climates.

### Stress

In addition to physical illnesses, there are also psychiatric disorders that can be linked with the new living environment, such as more frequent instances of schizophrenia in inner cities, although the

cause can also be said to lie in the attraction of inner city areas for sufferers of schizophrenia<sup>a</sup>. Although many tests have been carried out on sensoric deprivation (the lack of sensory stimuli)<sup>b</sup>, one should perhaps talk instead of 'motoric deprivation' in the modern urban environment, in other words, the lack of accompanying motoric sensations from the muscles, and, more generally, the awareness of one's own body and thereby of non-fictitious 'reality'. The time spent in the car, in front of a television screen, at a sports competition arouses all sorts of sensoric emotions which have no logical motoric counterpart. Stresses cannot be resolved motorically by physical exertion. This is one of the causes of obesity, heart and vascular disease. Where people live in close proximity to each other and where internal spaces are fragile, the 'motoric sequel' becomes systematically suppressed, from childhood onwards. This could provide an explanation for the popularity of sport and violence. Specialisation and the division of tasks splinter the unity of life, not only spatially (this happens here, and that there), but also in time (first this, and then that). The number of interfunctional activities is growing and is laying a heavy claim on tolerance to frustration, both for individuals and groups of people.<sup>297</sup>

### Division of space and time

People, animals, plants and apparatus need space and time to remain functional and to realise their aims or possibilities. At a certain level of intensity of use, they start to restrict each others' space and time so that displacement and waiting times occur, respectively. Systematic planning (spatial) and organisation (temporal) in the functioning of human beings and society become necessary as soon as either people or apparatus start to carry out, for example, more than 0.01 hr/m<sup>2</sup> of activities per year at a particular site (the present levels for agriculture in the Netherlands). If an activity takes place somewhere (a series of undertakings to meet a certain aim), then no other activity can take place on that same site and time. Therefore, if the intensity of use is greater than 0.01 hr/m<sup>2</sup>, one has to separate any two activities in space (planning) or in time (organisation). If a separation is made on a certain scale level, it is also necessary to connect it to another scale level when, from time to time, activities such as natural or economic cycles need to be linked. This combination of separations in general, and connections here and there, and now and then, is a form of selection. Each wall with a door, town wall with a gate, every prohibition with exceptions is a selector<sup>298</sup>.

### Separation

Separations in space and time can come into being because of physical regulations or by territorial and prodecral consensus ('you here, me there; now you, then me'). At higher scale levels, arrangements prevail; at lower levels, physical measures prevail. Consensus can be in the form of an order ('forbidden access'), which, in a democracy, is founded on delegating authority to give orders within certain areas of responsibility. Consensus can also be promoted by conducting an information or advertising campaign ('stop certain activities in this nature reserve' or 'come to the meeting'). As soon as activities can be divided by barriers, walls, arrangements or more informal consensus (culture) and then by (spatial or temporal) selective links brought into association with each other again (logistics!), then much higher intensities of use than 0.01 hr/m<sup>2</sup>-year are possible.<sup>299</sup>

### The intensity of use

Intensity of use is an important factor. It is one of the factors that determines to what extent an environment can be supplied with facilities (density of investment), by guaranteeing a certain level of utilisation. The intensity of use also determines the speed of aging, and is related to the contribution made to the national product, energy density, ecological pressure, and the risk factor in dangerous situations, etc.<sup>300</sup> Nevertheless, this measure is not used very much in Environmental Planning because it is difficult to estimate the use of time and to bring this to the same denominator as the use of space.<sup>301</sup>

In 1983, the intensities of use of various spatial functions were, approximately like Fig. 842<sup>302</sup>.

<sup>a</sup> Het verhoogd voorkomen van bepaalde ziekten zoals schizofrenie in bepaalde delen van de stad is in de jaren '70 geregistreerd door de GGD van Rotterdam. Daarbij kwam ook een andere causaliteit aan de orde. De omgeving leidde niet zozeer tot een ziekte, maar selecteerde de immigratie van probleemgevallen op andere kenmerken, zoals inkomen.

<sup>b</sup> Sensore deprivatie, het verstoken blijven van zintuiglijke prikkels, is dikwijls experimenteel onderzocht. Zie voor een kort overzicht van het onderzoek tot 1978: Jong, T. M. d. (1978) Milieudifferentiatie; Een Fundamenteel Onderzoek *Faculty of Architecture* (Delft) Delft University of Technology Jong, T. M. d. (1988) *Milieudifferentiatie* (Delft) DUT Faculteit Bouwkunde.

	hr/resident·year	m <sup>2</sup> /resident	hr/m <sup>2</sup> ·year
ACTIVITY			
In and around the house	6552	137	48
Learning away from home	374	6	62
Moving	387	91	4
Social/cultural	539	8	70
Recreation	162	47	3
Sport	36	17	2
Shopping	238	2	135
Agriculture	11	1667	0.01
Exploitation of minerals	1	5	0.3
Industry	185	30	6
Public utility companies	8	10	0.8
Building firms	71	20	4
Trade	51	3	17
Transport & communication	33	2	22
Other services	77	4	19
Government, etc.	61	1	102
Use of time: both paid and unpaid			

Fig. 842 Use of time/use of space = intensity of use<sup>a</sup>

**Urban uses of time**

Residents optimise their use of time to achieve a balance between maximising their income and the availability of free time and space. They have thereby long been prepared to accept travelling times of three quarters of an hour twice a day between their homes and their work<sup>303</sup>. Because of this, a tentative effect analysis can be made of the various urbanisation alternatives in this optimising process. By doing this, however, an impulse is given to far-reaching analyses of the economic, cultural and managerial effects.

**Choices on different time scales**

The use of time can be judged on different time scales: the daily rhythm, the weekly rhythm, the yearly rhythm and lifetime. On the first three time scales, the above-mentioned optimising process leads to recognisable questions of priority in everyone's life in the daily, weekly or yearly rhythm (see Fig. 843).

Am I going home early or late today?	Do I give priority to (a) the family or (b) to work?
This weekend:	will I be (a) at home or (b) am I going out?
This year:	will I be (living and enjoying recreation) (a) with someone else or (b) alone?

Fig. 843 Setting priorities in the use of time

	<tradition-directed				opportunity-directed>			
rhythm	A		S1				S2	B
daily	a	a	a	a	b	b	b	b
weekly	a	a	b	b	a	a	b	b
yearly	a	b	a	b	a	b	a	b

Fig. 844 Alternative uses of time

**Tradition- or opportunity directed preferences**

The (a) variants of Fig. 843 give more free time and strengthen the argument for national distribution and for Bundled Deconcentration; the (b) variants are conducive to more income and individual free

<sup>a</sup> NNAO, Ontspannen scenario, MESO Den Haag 1986

space, thereby strengthening the argument for concentration in the Randstad and for a Compact City strategy. Eight alternative uses of time can now be distinguished (Fig. 844).

These possibilities of using time lead to different opinions about how space should be organised. Political schools of thought can also be positioned in this scheme. Traditionally (<) oriented parties (such as the CDA) will choose (a) variants in all time scales (A); opportunity (>) oriented parties (such as the liberals) will choose (b) variants (B); and the socialists will differentiate the variants into 'blood groups' (S1 and S2) that are, respectively, more <tradition- or opportunity> oriented.

### Dispersion of time in space

These time-use alternatives also lead to another use of space between living, working and facilities and to another mutual proximity, other transport needs and to another economic accent.

Within the Randstad, however, there are boundaries to the maximalisation of collective free space within the opportunity-oriented perspective of urbanisation.

The process of specialisation and division of tasks in urbanisation, splinters the unity of daily and weekly life, both spatially (this is happening here, that there) and in time (first this, then that). In contrast to this, large and new freedoms have come into existence. We become about twice as old as we did at the beginning of the last century, and, in addition, have about twice as much free time. According to CBS (1994) since World War II, the number of people per dwelling has halved, from 5 to 2.5 people, so that, within a radius of 10 metres ( $R = 10\text{m}$ ), we have at least twice as much space. Within a radius  $R = 100\text{m}$ , we have small areas of green, and within a radius of  $R = 1000\text{m}$ , large areas of green. We are suburbanised *en masse* in order to have a magnificent view close at hand. And there the story comes to a halt, because on each higher scale level, the emptiness disappears.

### Political parties choose different 'accords' of dispersion

Historically, the preferences for traditional- or opportunity-oriented uses of time can best be read against the aims of political parties with respect to space, expressed in their programmes over a period of 40 years as the University of Amsterdam once found out. They can be styled in 'accords' of the concentration (C) and deconcentration (D) of urban areas on national, regional and local levels (see Fig. 845 and Fig. 700)

In a radius of	100km	30km	10km
	(sub)national	regional	subregional
Liberal	C	D	D
Socialistic	D	C	C
Christian-democratic	D	C	D
'Purple'	C	D	C

Fig. 845 Political 'accords' of dispersion

Traditionally, the liberals have wanted a national concentration of urban areas, because that would benefit the competitive position of the Randstad. On regional and local levels, however, they have always preferred deconcentration to allow free choice of place of residence or establishment. In contrast, up to the 1980s, the socialists favoured deconcentration on the national level to encourage a fair distribution of residence and employment opportunities throughout the country, but concentration on the regional and local level for the benefit of public transport and the political cohesion of minority groups. To preserve the historical identity of the provinces, the Christian Democrats have favoured national deconcentration. On a regional level, they have favoured concentration in order to have provincial capitals with recognisable regional religious and civil administrations. On local levels, they again favoured deconcentration (suburbanisation) because, in their view, only small communities can offer a caring society in which the family, the corner-stone of society, can flourish. In this way, freedom, equality and brotherhood become recognisable and controllable in different design principles and on various levels of scale.

### Changing preferences in national plans

But policies change by different coalitions as you can see in the successive National Plans in the Netherlands (see Fig. 846)

In a radius of	300km	100km	30km	10km	3km
2 <sup>nd</sup> National plan 1966	Bundled Deconcentration				
	theory		C	D	C
	practice		D	C	D
3 <sup>rd</sup> National plan 1983	Structuurschets Verstedelijking 1978: 'new towns' ('PTT naar Groningen')				
Socialist period		D	C		
	Structuurschets Stedelijke Gebieden 1983: 'growth towns'				
Liberal period		C	D	C	
4 <sup>th</sup> National plan 1988	Compact city: nodal points				
	C	C	D	C	

Fig. 846 Changing preferences in national plans

The result of these changing policies is urban sprawl (see Fig. 701).

### Freedom of choice supposes diversity

The largest number of possibilities for future generations will be achieved by realising maximum diversity in environments. Determining which scale levels require which forms of diversity (legends), is the most important task that urban architectural research has to face. The composition of the population and the life cycle of every individual provides changeable patterns of time-use, and, for this, specialised spaces are needed. One 'best' overall solution is the worst solution. The intermediary forms between On-going Deconcentration ( $D_{100km} \dots D_{10m}$ ) and Complete Concentration ( $C_{100km} \dots C_{10m}$ ) probably offer more possibilities than these extremes in themselves, but they also eliminate future possibilities for the Randstad, such as the availability of free space of the size of the Green Heart that can only be achieved where there is complete concentration. However, that, in turn, interferes with the identity of towns and cities, would require abandoning buffer zone politics.

## 6.1.5 Mobility between urban populations

### Forces of attraction between masses

According to Newton (1687, beautifully described by Feynman, Leighton et al., 1977, 1963), the attracting force  $F$  between masses  $M_1$  and  $M_2$  is inversely proportional to the square of their distance  $d$ :

$$F(d) := G \frac{M_1 \cdot M_2}{d^2} \text{ (Newton, 1687),} \quad \text{while } G := 6.67259 \cdot 10^{-11} \cdot \frac{\text{m}^3}{\text{kg} \cdot \text{sec}^2} \text{ (Cavendish, 1798)}$$

The factor  $G$  was measured by Cavendish with a precision of 1% and until now again and again with greater precision. The formula inspired traffic engineers to formulate the travel benefit between urban populations in a comparable way.

### Traffic flows by attraction

Human behaviour is more difficult to model than lifeless matter, but, because of their large numbers, in the long term, people's improbable individual choices cancel out one another statistically into a main probability. So, traffic between urban units can be modelled reasonably well in proportion to their population, taking into account their mutual distance.

If we represent moving people between sites of departure and destination according to their masses, then the Newton formula can be adapted to actual reality. For example it can be adapted by taking a power in the denominator of Newton's formula (see page 471) other than the square '2'.

### Calculation traffic according to Newton's formula

Completely according to Newton, the power of attraction between two urban units would be proportional to their populations  $p_1$  and  $p_2$  and inversely proportional to the square ( $b = 2$ ) of their

mutual distance  $d$ . But if you make  $G=a=1$ , you take the mass of both poles as 100 and change the power  $b$  into 3 or into 7, then the function starts to look like the use of different slow ( $b=7$ , like bikes) or fast ( $b=3$ , like cars or trains) means of transport (see Fig. 847).

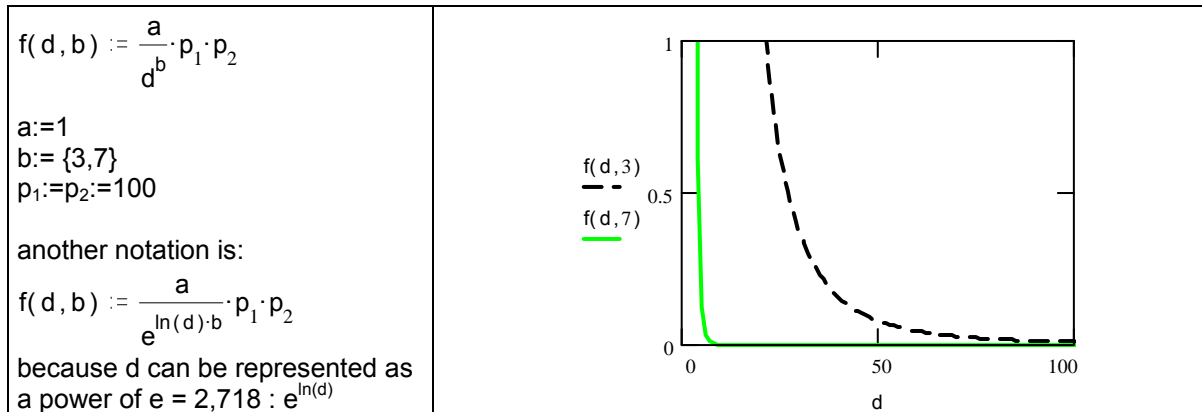


Fig. 847 Traffic according to a modified Newton formula

However, according to this graph, direct neighbours must exert a strong, almost infinite, force of attraction, like lifeless matter does. In the case of humans, this would mean that every desire to travel further would disappear, because the benefit of staying home is infinite. Consequently, for travel calculations the coefficient  $a / e^{\ln(d) \cdot b}$  of the populations  $p_1$  and  $p_2$  has to be adapted.

### Adapting the coefficient of the populations

To make that coefficient maximally equal to scale factor 'a' taken as 100% ( $a = 1$ ), we have to make the denominator minimally 1 by adding 1:  $a / (1 + e^{\ln(d) \cdot b})$ . Then, if scale factor  $a = 1$  and the distance  $e^{\ln(d) \cdot b}$  is zero, the force of attraction is 1 or 100% (see Fig. 848).

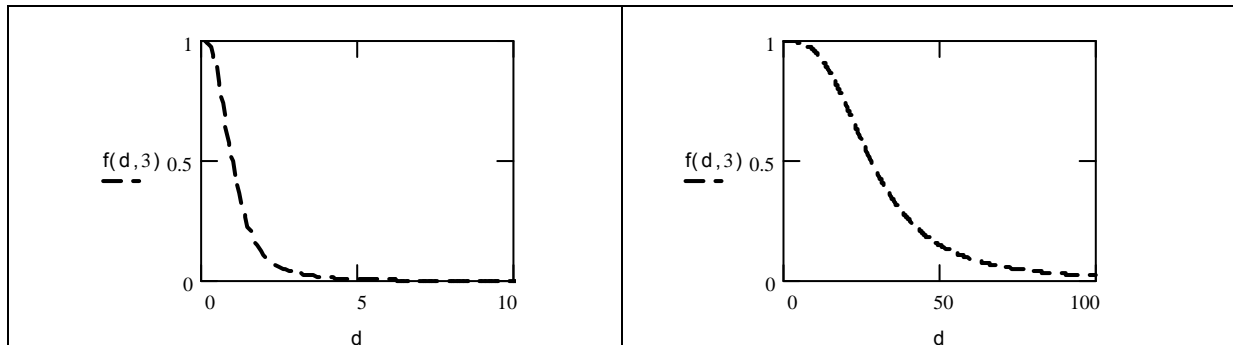


Fig. 848  $f(d, b) := \frac{a}{1 + e^{\ln(d) \cdot b}}$

Fig. 849  $f(d, b) := \frac{a}{1 + e^{\ln(d) \cdot b - \beta}}$

The graph now starts beautifully at 1 at a zero distance, but by a growing distance the attraction by fast traffic decreases to zero already below  $d = 5$  in Fig. 848. To stretch the graph you can subtract a constant  $\beta$  from the power:  $e^{\ln(d) \cdot b - \beta}$  (see Fig. 849, where  $\beta=10$ ). In the mean time, this application shows the advantage of using the power of  $e$  instead of a power of  $d$ .

### Attraction reduced by costs and distance < 30km

In addition, the model also has to take into consideration that not only the distance, but also factors such as congestion or useless delay, can reduce the effect of masses attracting each other. All such 'costs', including travelling time, partly increasing due to distance  $d$ , are summarised in current traffic models by the term 'travel resistance'  $c$  (costs, see Bovy, P.H.L. and N.J. van der Zijpp 2000). Between two populations, this travel resistance is operationalised in the travel benefit function  $f(c)$  as an effect of  $c$  (including distance  $d$ ). This function reduces the attraction of the masses: the higher the costs, the smaller the travel benefit.



### Travel benefit related to costs, calculated by traffic engineers

If the parameters are chosen well, Fig. 850 is supposed to fit in with the current empirical reality. In the graph, the travel cost  $c$  can be largely identified with the distance travelled in kilometres.

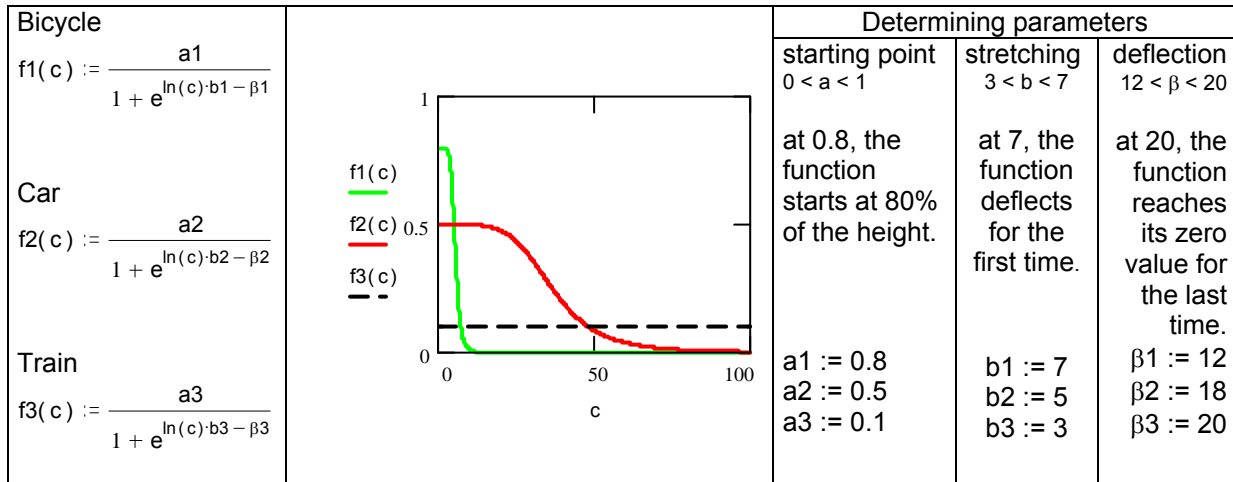


Fig. 850 The type of log-logistic travel benefit function that is used in the WOLOCAS model, with which new VINEX districts were calculated<sup>a</sup>

Thus, one can read from this that the travel benefit of a car is, on average, greater after about 5 km than that of a bicycle. After about 50 km, the travel benefit of a train is greater than that of a car.

### Modal split

However, at zero distance there is of course no traffic, and looking at empirical statistics of different traffic modes (see Fig. 851), the curves do not look like the log-logistic utility curves of Fig. 850.

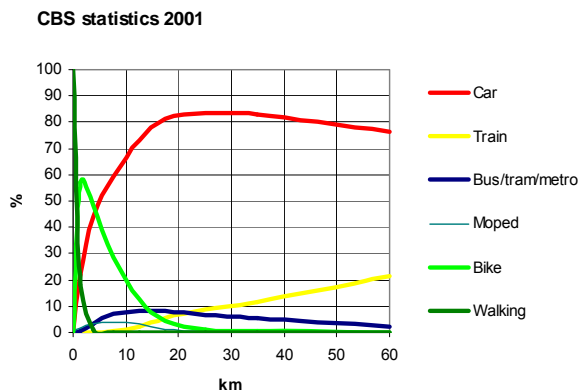


Fig. 851 Modal split

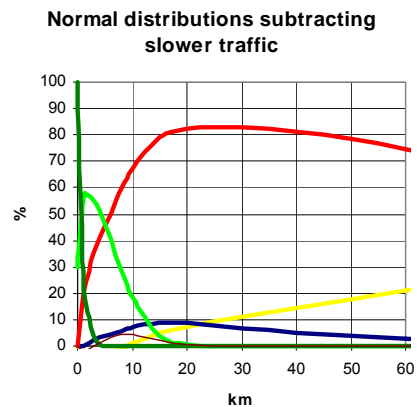


Fig. 852 Simulation of Fig. 851

They look more like normal distributions drawn crooked to the zero distance border. If you simulate them like that, the walking pedestrians and bikes look like a halve of such a normal distribution. The curve of the car can be simulated as a normal distribution, partly diminished by subtracting the curves of walking pedestrians, bikes and mopeds like Fig. 853 shows.

<sup>a</sup> Bovy, P.H.L. and N.J. van der Zijpp 2000

	walking	bike	moped	car	bus&	train
vertical scale factor	100	1000	100	15800	10000	11500
average at	0	0	7	25	-30	100km
standard deviation	1,5	6,4	5,5	76,0	100,0	100,0
subtract walking		20%	0%	75%	40%	30%
cycling			10%	75%	41%	40%
moped				0%	15%	30%
car					32%	27%
bus, tramway, metro						40%

Fig. 853 Figures, used for the simulation of Fig. 852

## 6.1.6 The urban field is not homogeneous

### In between two highway exits or (public transport)stops

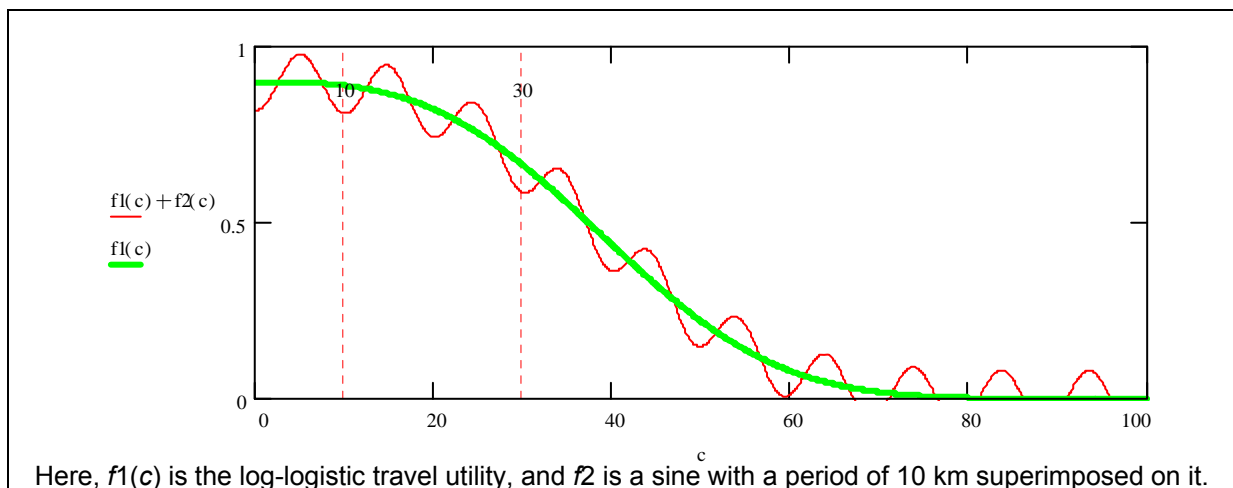


Fig. 854 Fluctuations of travel utility with a periodic infrastructure of 10 km

In practice, the travel benefit formula does not always decrease with an increasing distance or 'travel resistance' by costs  $c$ . The formula is true in a homogeneous field, but not in a heterogeneous field of a network with exits or (public transport)stops. Everyone knows that taking an exit further on can sometimes result in more travel benefit. Suppose that the mesh width and exit distance of local highways is 10 km on average. Suppose from my departure point, it is a 5 km drive to the next local highway. Then, after 10 km, I am on the motorway, between two exits. In that case, the travel utility of 10 km is smaller than that of 15 km. The graph could therefore fluctuate when a radial motorway has an exit every 10 km (see Fig. 854).

#### Useful destinations increased by distance

For a train, these fluctuations are caused by the station stops: I cannot end my train journey between stations in the event of my seeing no utility any more in continuing the journey. With regional tracks occurring regularly, every 30 km, even more fluctuations with a 30 km period are superimposed on them.

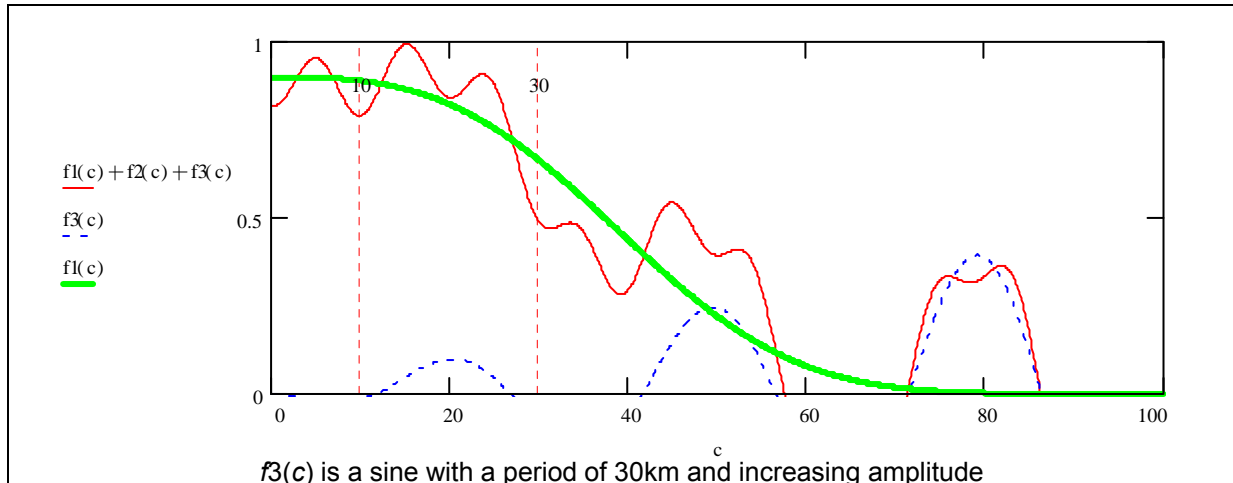


Fig. 855 *Fluctuations of the travel utility with a periodic infrastructure of 3 and 10 km and with increasing travel utility*

### Passing rarified zones without direct utility

It is clear that, in this case, travelling 50 km has more utility than 40 km. In addition, the higher design speed on these speed-specialised lines, less plagued by stops and exits, lowers travel resistance, so that the kilometres used to calculate  $c$  shrink in travel time. I will leave these sorts of mathematical complication to more experienced calculators.

The conclusion could be that well-thought-out construction or improvement of fast infrastructure results in rarified zones designated as green areas, which are positioned radially around human masses in the direction of other masses, and have a greater travel utility for intersections situated further away than for the pure log-logistic decreasing travel utility functions without fluctuations. This is a beginning of the traffic concept for an interregional network city.

### Broadening the travel horizon increases the number of attractive destinations

Without a division of tasks, broadening the travel horizon in a homogenous urban field increases the accessible area, and thus the destination possibilities by the square of its radius. The proportion of these possibilities that is actually utilised within an available budget in the form of money, means of transport and time, is the scale factor  $a$ . That factor becomes smaller the further (and faster) I travel to obtain these possibilities. One can take this increasing travel utility into consideration as an effect on the costs of primarily decreasing travel utility function  $f(c)$ , with an increasing amplitude of stops or exits situated further and further away. In Fig. 855, it is thus assumed that, at the first and second exit or stop on these lines, the utility, and thus the amplitude, will increase due to increased destination possibilities. This effect is strengthened by interregional task division.

### Attraction between regions charged with task division benefit

In the current model philosophy, a positive travel utility is expressed more purely as a factor of the power of attraction of the masses, than just by the mass-effect-reducing travel utility function  $f(c)$ . For each urban concentration, a traffic model can apply separate empirically determined corrections to the mass effect. However, in the case of interregional task division that is not logical. The power of attraction between regions, due to increasing interregional task division, appears to be more like electromagnetic attraction caused by a difference in positive and negative charges, which supplement one another. However, where there are more than two tasks, there are more sorts of charges than + and -, and the range is greater. It is essential that the attraction is not a characteristic of a mass, itself, but of its specialisation compared with other masses that are charged differently. Alternatively, equal charges cause repulsion. For this, a separate, not necessarily reducing, but accrediting, specialisation function will perhaps have to be devised.

### Making lost time useful

Then, in working out the travel resistance  $c$  itself, the travel time as a cost post will be taken as being almost synonymous with distance and other inconveniences. However, travel time can be used as

contact, work or rest time *en route*. In particular, it will be possible to facilitate work time in the future by means of communication technology. The remaining travel time does not always increase with distance, but is mostly due to slowness and delays when changing from one form of transport to another, and this can be included in *c*. This is why the design of multimodal intersections and means of transport, and their multifunctional, urban integrated and communicative equipment, is the primary project for a Delta metropole. At the same time, the most important item on the agendas of managers, designers and key actors is the mutual determination of the identity of regions, agglomerates and towns with respect to growth in task division. The new public transport between them must not eliminate chance, but organise it. One cannot confine oneself, then, to adapting *c* in existing models on the basis of empirical starting points, when some costs can be changed into benefits by shrewd design.

## 6.1.7 The force of specialization

### Attractions >30km

About 90% of all traffic movements are kept within a radius of 30 km (region) around the departure address. It is natural that traffic modelling focuses on that section. Commuter traffic generates the problems that traffic specialists are hired to solve, so they gear their models to these.

As far as I am aware, there is still no model for the individual and collective benefits interregional traffic (> 30km radius), caused by regional specialisation. The attraction of mutually specialised masses should be greater than that of mutually unspecialised masses. Why would people travel at all, if there is no difference between departure and destination? And if a difference far away promises great profits, how important is distance then? If functions are specialised on a larger scale traffic benefit can increase with distance.

### Exchange, traffic implies specialisation

Trade rests on that principle, and so does the ecological division of tasks between land and water, and between male and female flowers that exchange their life experiences with the help of insects, the travellers. On every scale level, life itself shows the evolutionary effects of specialisation: combination by exchange. The attraction of Disneyland has another travel benefit function than commuter traffic, certainly when Parisians are becoming bored with it.

### External specialisation by internal integration

In the Dutch Golden Age, Zaandam<sup>a</sup> produced ships, Amsterdam used them. Amsterdammers with initiative felt more at home in Indonesia than in Zaandam near by. Regular destinations far away create an unknown zone close by, also recognised for commuters by Groenman (1960) as 'ijle zone'. But that zone has its functional integration by other specialised populations. During the period concerned, Amsterdam, already a metropole with 100,000 inhabitants, became a world city with a national web of punctual towing boats (Vries, Jan de 1981). About 1600 AD the organising of the VOC by Van Oldenbarneveldt (Romein, J.M. 1938, 1971) gave each of the United States of The Netherlands its own commercial part of the world changing mutual competing and conflict into cooperation. It was external specialisation by internal integration. Disneyland in Paris is a similar improbable example of organisation and offshore entrepreneurial spirit. Organisation is a matter of specialisation and combination.

### External effort outgrowing internal integration

However, our colonial past gives reason for us to be ashamed of expansion, certainly if it costs too much energy. Ever since Stadtholder Willem III, setting sail from Hellevoetsluis, exported our commercial democracy to England by conquering it, in a final effort, with an armada three times larger than that of the Spanish, (Israel, Jonathan I. 1995), we would rather stay closer to home. Ever since Thomas Jefferson visited our country in order to study our republican constitution (Eskens, E. 2000), the roles have been definitively exchanged with Anglo Saxon players. From Scherpenzeel (birth place of Peter Stuyvesant), no one will establish a New Amsterdam again, if there is still enough space in neighbour village Munnekeburen. Now investments from New York are welcome. Whether foreign investments will come or not, again depends on the percentage of key actors who, sometimes by chance, discover that it would be better to grow (for example) coffee outside one's own region, than at home. If people are alert, this will not lead to exploitation this time, but to cooperation.

<sup>a</sup> In Zaandam the Russian Tsar, Peter the Great, learnt to build ships.

### **Travel benefit fluctuating by distance**

Between the region and the world, however, there are still a number of scale levels on which the travel benefit can be increased for some destinations by including rarified zones, for example green areas close to home. If we show a collective will for fast lines of interregional public transport, communication and decisionmaking, then the travel benefit function in the travel models can be adjusted. However, the question is: On what level do we want to spread our towns and green spaces? Bundled deconcentration within the region (NRO2, RPD 1966, see Fig. 700 and explaining text) has been disposed of since 1983 (NRO3, RPD 1983, see Fig. 846): it broke up the green spaces in urban landscapes. Its variant, a regional network town, breaks green spaces into even smaller pieces.

### **Declining specialization by local congestion**

The compact city (RPD 1988, see Fig. 846) increases travel resistance locally due to congestion, whereby the strength of cooperation between the big cities decreases in full accordance with prevailing traffic models. That is a self-fulfilling prophesy. Wings that do not divide their tasks, but without sufficient coordination go their own way, are probably unable to make an international flight. Moreover, in the unintentionally expanding compact city, green areas are only accessible by car. In addition, on public holidays, part of the free weekend is claimed by traffic jams. That can only be compensated by holidays in further-away places that make a joke of the travel utility function. The result is a vicious circle of local travel resistance and less cooperation based on reliable specialisation.

### **External competition by internal cooperation**

The Delta metropole is not a regional, but an interregional network city. It is a world city not because of its masses, but because of spatial specialisation. Urban masses become more attractive, if better and faster decisions can be made than elsewhere in the world. That saves the energy of interregional competition for attracting international acclaim. International power is achieved through interregional cooperation, based on a division of tasks. In doing that, one aspires to create an international site and expansion base for business establishments with extensive green and blue spaces within cycling distance from home.

### **Regional division of tasks**

The classical *trias urbanica* of management, culture and market is recognisable in the centre of every medieval town, where townhall and church made space for the market. This is where the surrounding consumption and production converge, managed in the town hall, reflected in church. This territorial division of spaces by task has, since then, been subject to scale enlargement. Until after World War II, Bonn, Cologne and the Ruhr area, The Hague, Amsterdam and Rotterdam had divided these tasks interregionally to give managerial, cultural and economic accents, respectively. Due to the movement towards a service economy after the war, cultural identity came to have more of an economic meaning.

### **The right diversity on the right scale**

A culturally equipped town or city furthers the chance of a productive meeting. Thereby, Amsterdam, gained better chances of being chosen as a place of settlement by the key actors responsible. Rotterdam and the Hague regained a cultural identity by means of international film and jazz festivals, unmatched architecture, and decision-making culture. Making faster and better decisions requires the lubricant of cultural eye-opening. In the much smaller, but more central, inland Utrecht, the 'captains of service' confer at the crossroads of polders, rivers and forests, with dunes and harbours on the horizon. Here too, the converging peat, clay and sand diversify ecosystems while from here they determine more uniformly the ecology as far as the Urals (Constandse, 1967). Also in the opinion of the youngest generation, growth should not be concentrated there.

### **Direct, distribute, disperse and concentrate on the right level**

There, key actors from the heart of Europe are shown a route via the Rhine axis in their Delta over the Mondriaan-like network called Holland (see Fig. 856).



Fig. 856 Potential continental, fluvial and national network systems<sup>a</sup>

In addition, in the Delta, rail and road transport via the south and east can be brought together on an even greater scale along the European coasts to choose our water and air space as main ports (and the reverse). This will be achieved, if the foreign actors are received in a well-considered, cooperative network of towns, each suited for its own task, attractiveness as a place to settle and with its own identity. There are large projects with small consequences and small projects with large consequences. The Delta metropole is not directed towards projects in which the one section expects to dominate the other, but, in the end, steals an advantage.

### Limitation shows the master

Does one section choose projects that deprive the other of success, or can people delegate among each other so that, together, international functions can be given the best position in the whole network? The latter requires subnational decision-making skills, regional loyalty and again local decisiveness. If one chooses non-traditional regional solutions, using traditional national means, the Delta's inherited urban constellation can be turned into an international novelty. One can grow interregionally by trimming regionally, integrating by mutual specialisation, by accepting one-sidedness in order to excel, and by developing the rest elsewhere.

### Specialisation as a paradox of scale

Managerial initiative, innovation, growth, integration and versatility are a question of scale. In contrast, on another scale, they require loyalty, tradition, trimming, specialisation and one-sidedness. The implicit presuppositions of the Stedenland perspective (VROM 1998) that preceded NRO5, illustrate this kind of scale paradox. They are made explicit in Fig. 858. That perspective supposes national initiative and subnational laissez-faire, national tradition and regional innovation, national division of tasks, subnational integration, national concentration, local dispersion.

<sup>a</sup> Jong and Paasman (1998)

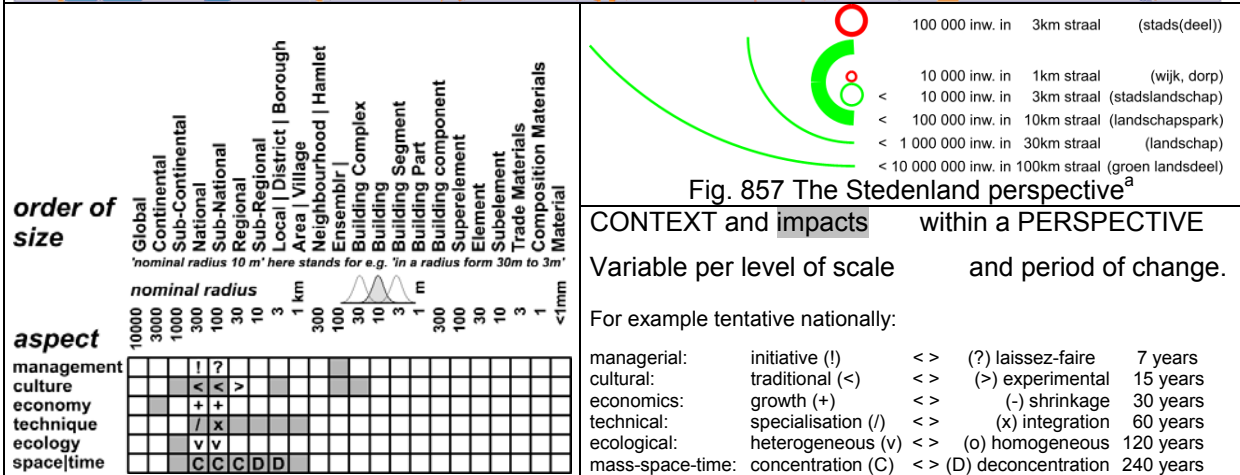
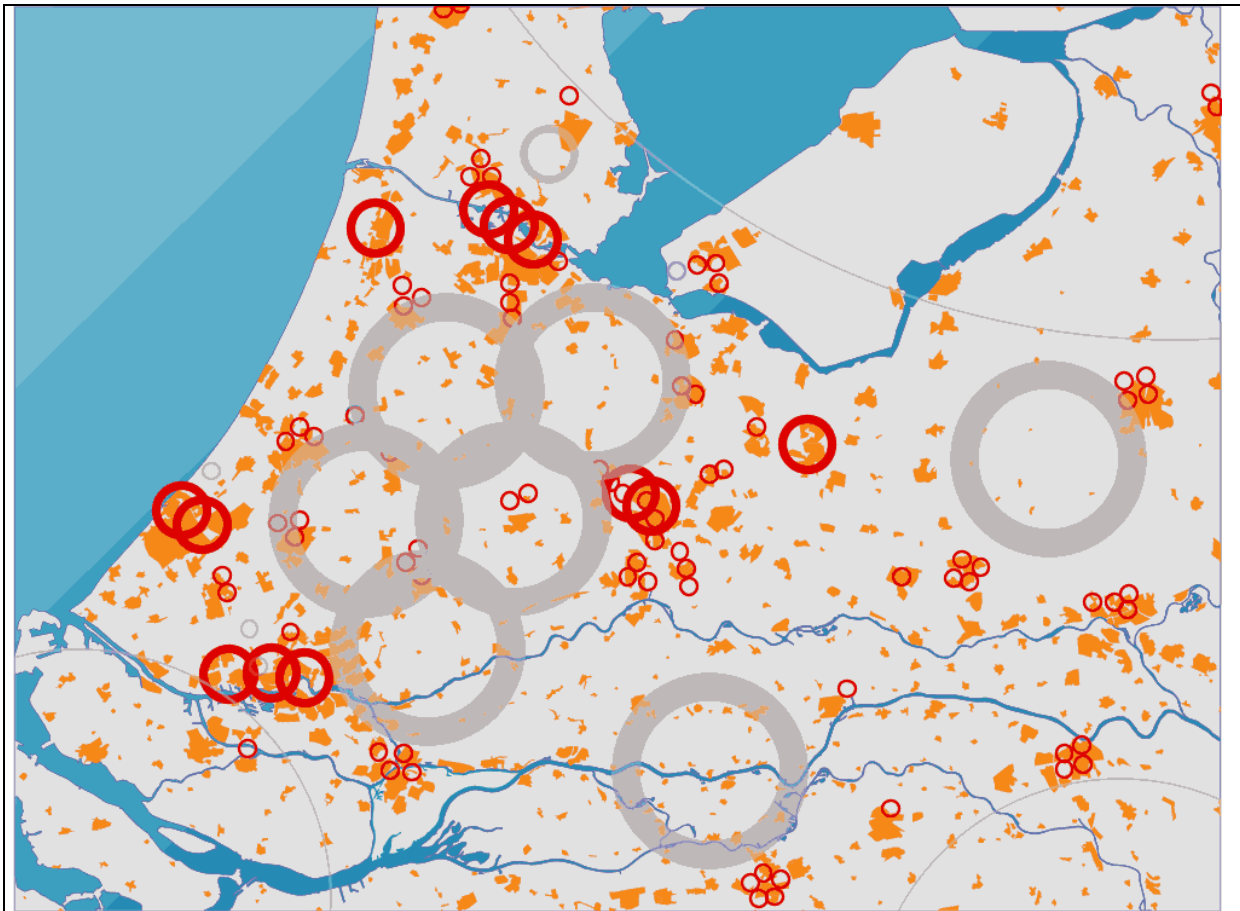


Fig. 858 Context organ (example: the Stedenland perspective (VROM 1998) and effects (grey))

According to the combinatorial system, it is possible to play  $10^{65}$  other chords/accords on this organ. The Delta metropole accord is much the same. The difference is that subnational deconcentration and a great effort to achieve technical integration that facilitates the division of national tasks has been requested (VROM 2001, 2002).

### Specialisation supposes exchange

The division of tasks consists not only of where projects are established, but also the network. A didactic rule of thumb that, for each higher unit of road system, an approximately three times larger mesh width should be maintained, turned out to be more realistic than was first thought. It has been calculated in three different ways that, by doing this, an optimum of accessibility and construction

<sup>a</sup> VROM 1998



costs is achieved (Nes, R. van and N.J. van der Zijpp 2000). However, this would mean that, in the Netherlands, there would have to be nine orders, each with its own design speed and exit frequency (Jong, T.M. de and M. Paasman 1998): continental, fluvial, national, regional, local motorways, urban motorways, district, neighbourhood and residential streets drawn with a mesh width of 1000, 300, 100, 30, 10, 3, 1, 0.3, 0.1 kms, respectively, if one draws the same mesh length and breadth. The first three are drawn in Fig. 856, and if one styles the remainder, then one gets a typology of dry connections with square meshes, as shown in Fig. 492. These can be stretched using the same mesh density as shown in Fig. 495.

### Calculating missing links or simply drawing them?

In the absence of exact knowledge about departure sites and destinations, designers can sketch in the missing links with transparent, squared elastic paper. The design will alternatively consider first the network as the directing force and then the settlement site (Angremond, Kees d', Pieter Huisman et al. 1998; Jong, T.M. de 1998). However, very many exits would have to disappear to improve travel times and safety (Reuzer, Bart and Marijn Schenk 1999). Though, especially within towns, the national strategy is to reduce the number of orders at the expense of travel time, but in favour of an assumed safety (Duurzaam Veilig; Sustainable Safety Project). Therefore, the current travel benefit function remains calculable and negative. Is that what we want?

### Networks between specialised cities

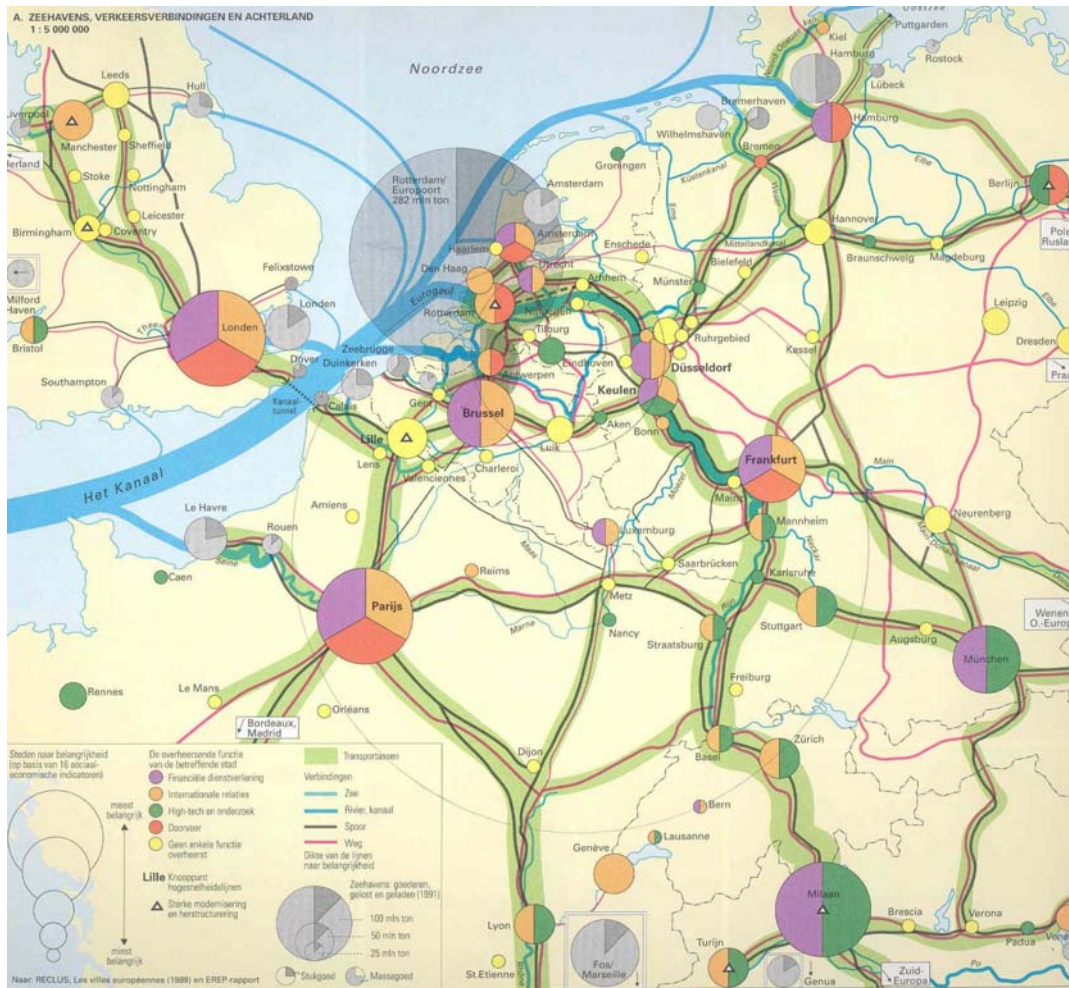


Fig. 859 Population, socio-economic weight and connections in a radius of 1000 km<sup>2</sup>

Fig. 859 gives a global impression of the population of central Europe in 1996, with the highest densities shown along the Rhine. This figure also shows those centres that score highly in a large

<sup>a</sup> RECLUS, Les villes européennes (1989) and EREP-rapport, cited in Wolters-Noordhof (1996)



number of socio-economic factors. The highest scores are for London, Paris and Milan. Centres of secondary importance are Brussels, Frankfurt and Munich. Amsterdam and Rotterdam are aligned with a large number of centres of tertiary importance. The beginnings of a 21st century network, with a mesh width of approximately 100 km are also visible in this figure. Southern Europe and the large population of eastern Europe are attempting to join this economic network. Railways parallel to the northern and western coasts form a forerunner and starting point for, what is still, a hypothetical 300 km grid (see Fig. 856. The Netherlands is situated in the corner of this grid, as a terminal with main ports for transfer to air and water.

## 6.2 Habitat

### 6.2.1 Dutch heritage

#### The physical identity in Europe

At the end of the 20th century agriculture, due to a reduction of its market coupled with higher productivity, lost its primary position in national self-sufficiency. Globalisation leads to a division of tasks internationally as Steekelenburg (2001) elaborates. The main task for the Netherlands is trade and the conservation of rare natural areas.



Fig. 860 *Potential natural vegetation*<sup>a</sup>

The lowlands of Zeeland, Holland and Friesland as a whole, with a boundary consisting of young dunes and older ones, up to 5000 years old, together with their potential vegetations, are viewed as rare on a European scale, within a radius of at least 1000 km. Dyke construction has enlarged the area and diversity of the land in the course of a 1000 years, with Old Marine Clay polders and

<sup>a</sup> RIVM (2001)

reclaimed land, albeit to the detriment of rare saline plant communities. By doing this, the largest area of potential estuarine vegetation in north-western Europe has come into being.

Further inland there is a just-as-rare and irreplaceable zone of potential reed swamp / swamp forest. 'From Amersfoort to the Urals, one does not encounter another landscape that is so full of big surprises' (Constandse, A.K. 1967). Further up-stream lies the largest, though less rare, area within this radius, of river-dependent vegetation.

### Rare in The Netherlands, common in Europe

The sandy soils, situated on higher ground, form the beginnings of a potential European oak-beech forest. Although not a rare form of vegetation, these forests are highly valued nationally as recreation areas. Ecologically, pine forests in our country are viewed as recent, artificial anomalies.

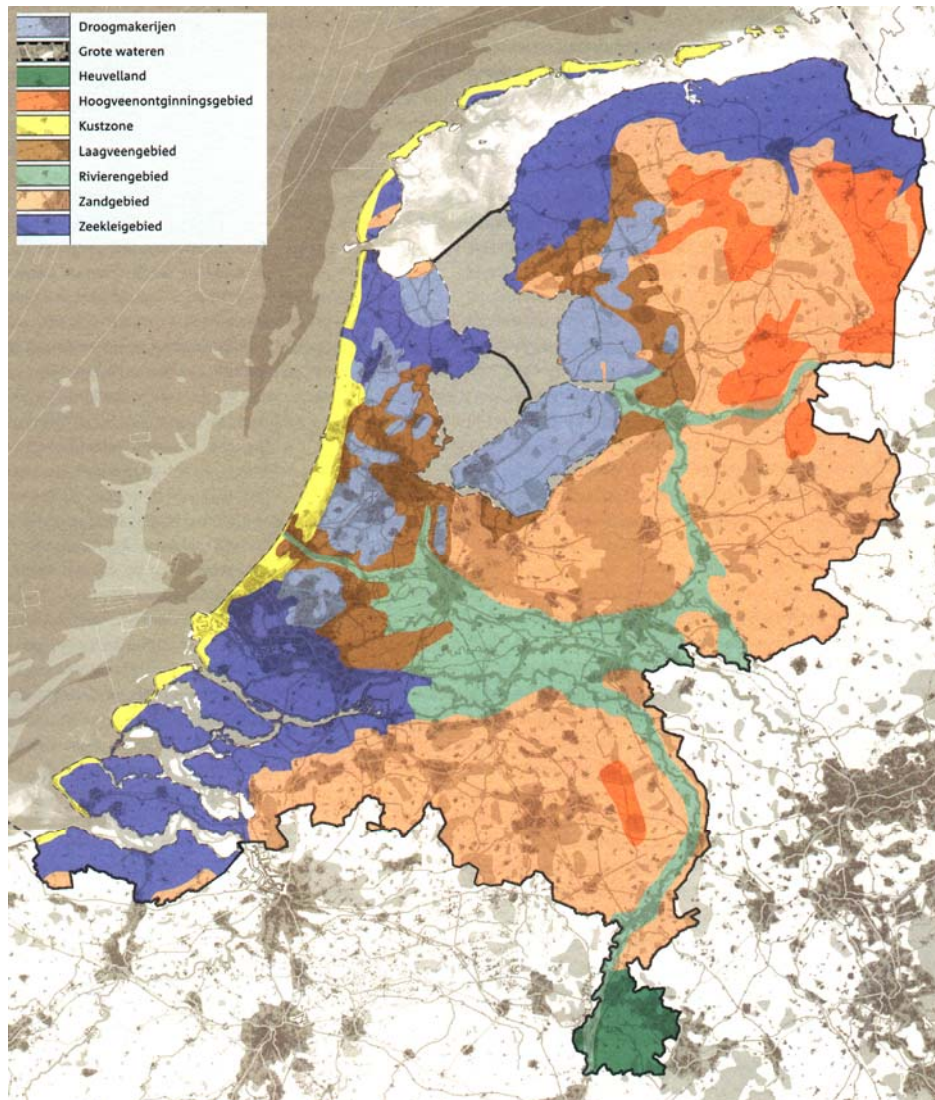


Fig. 861 *Nine types of landscape*<sup>a</sup>

### Rare in Europe, common in The Netherlands

If one looks in more detail at these important international possibilities (in a section of 60 x 60 km), then the landscapes of very great significance that one recognises are the Old Marine Clay polders, the reclaimed land and the peat exploitations in our country in the neighbourhood of Leiden. In addition, the mud flats (Wadden), the dunes, the Young Marine Clay polders, fluvial basins and ridges

<sup>a</sup> LNV (2002)

are also of great international importance. The landscape types identified by LNV show the Old Rhine to be an extension of the fluvial area, surrounded by areas of peat lying below the present water table (*laagveen*), bordering on areas of Marine Clay. On both sides of the Old Rhine there is an interesting series of potential transitions.

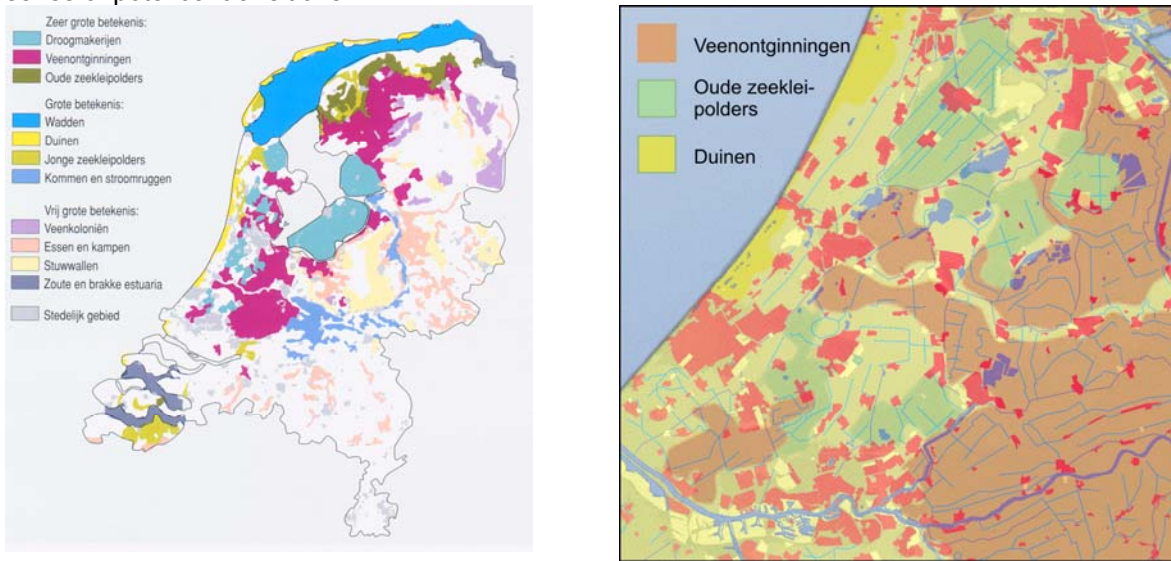


Fig. 862 Internationally important landscapes<sup>a</sup>

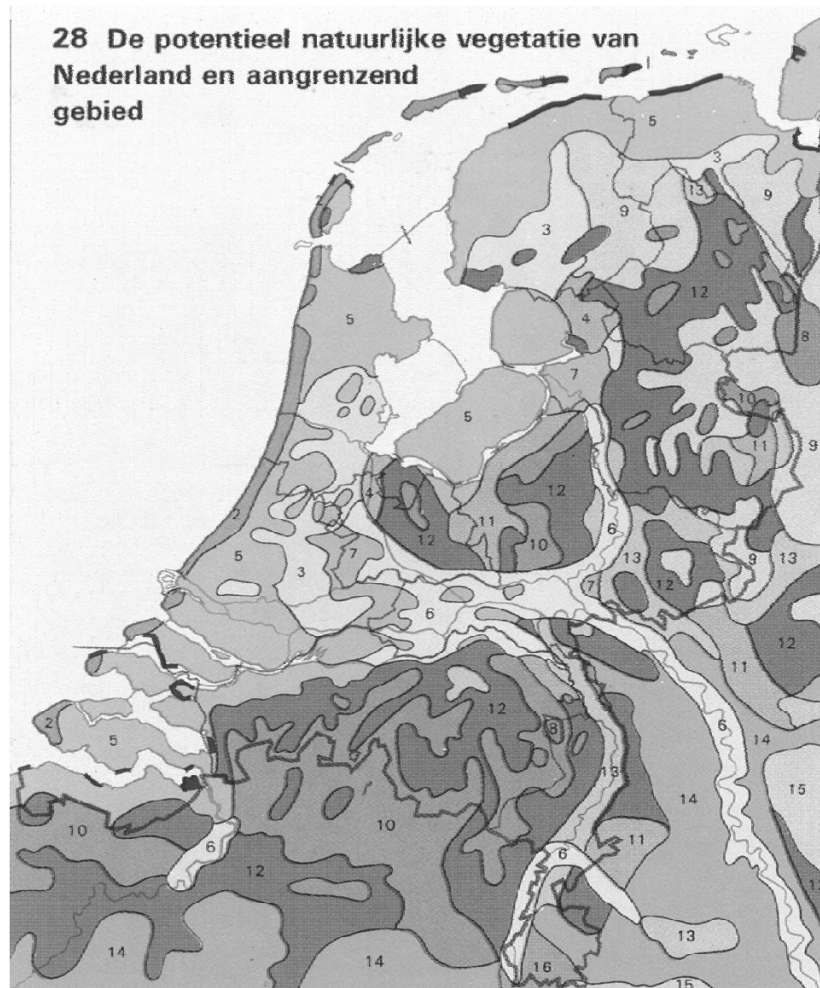
<sup>a</sup> RIVM (2001) page 16 ; LNV (2002)



## 6.2.2 Human impact

### The Netherlands undisturbed

If, apart from providing a stable system of water management, the Netherlands would be left undisturbed by human beings from now onwards, then the following forests would come into existence:



#### Legends

- 1 salt-marsh vegetation with, among other plants, sea lavender and salt-marsh grass: transitions from a salt to fresh-water environment.
- 2 dune heath, -grassland and -thicket, dune birch forest and dune oak forest, birch– common oak forest
- 3, 4 marsh fern–alder swamp, and similar
- 5, 6, 7 ash–elm forest, and similar
- 8 blanket bog, and similar
- 9 moist alder, birch, common oak forest
- 10 dry birch–common oak forest
- 11 moist durmast oak forest, and similar
- 12 dry durmast oak, and similar
- 13 oak–hornbeam, and similar
- 14 millet grass–beech, and similar
- 15 woodrush–beech forest with oak
- 16 beech forest, alder- and ash natural forest, and similar

Fig. 863 *Potential natural vegetation*<sup>a</sup>

<sup>a</sup> Sticht. Wetensch. Atlas\_v. Nederland, Piket et al. (1987) page 13

Only where water floods the land regularly or for a lengthy time, where wind moves sand, and where grazing animals keep meadows in forests open<sup>a</sup> would vegetations other than forest be able to maintain themselves.

### Human impact

Against the background of this 'nil variant', in the following paragraphs the effect of human intervention is demonstrated in images that have been developed by the University of Utrecht (see Fig. 72)<sup>304</sup>. The influence of humans expresses itself in draining, raising, hardening, digging up, treading upon, burning, systematic grazing, mowing, ploughing, harvesting, fertilising and polluting. Because of these activities, earlier stages of plant successions are kept in existence artificially.<sup>305</sup>

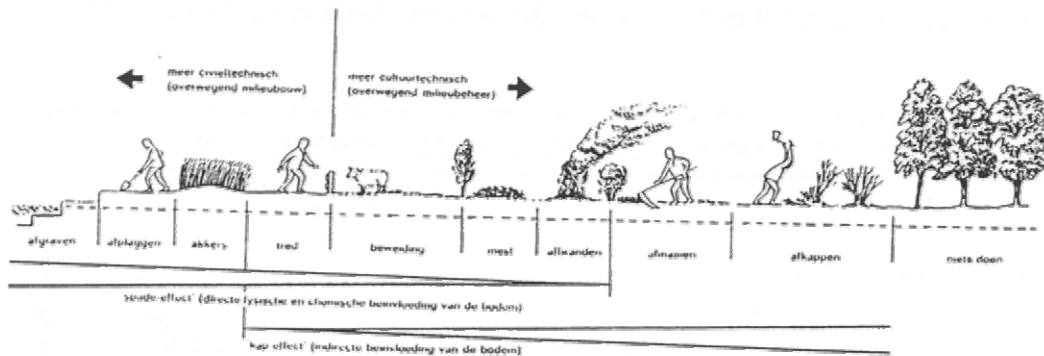


Fig. 864 Human interventions in relation to dynamics<sup>b</sup>

### Decreasing 'culturalness' around settlements

For centuries, this 'anthropogenically added dynamic' decreased with the distance from residential buildings

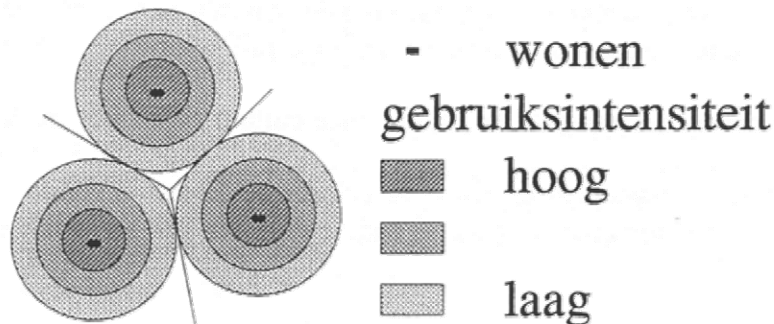


Fig. 865 Intensity-of-use gradients around farm and town<sup>c</sup>

The intensity-of-use gradient around farms and towns was strengthened by a mineral gradient. For centuries, traditional agricultural systems have enriched local soils with minerals to the detriment of poorer soils further away, that thereby leave behind specialised, and thus rarer, types of vegetation, such as hay fields, heathlands, shrublands and forests. Where people stored minerals for use in agriculture, only a few rapidly maturing species grew there. However, where people removed them, an increasing diversity of slow-growing, but uncommon, specialist species, cooperating of necessity in ecosystems, grew undisturbed and in scarcity. Over the centuries, this has led to an increase in the number of plant species.<sup>306</sup>

<sup>a</sup> Vera, F. (1997). *Metaforen voor de wildernis*. ('s-Gravenhage) Ministerie van Landbouw, Natuurbeheer en Visserij.

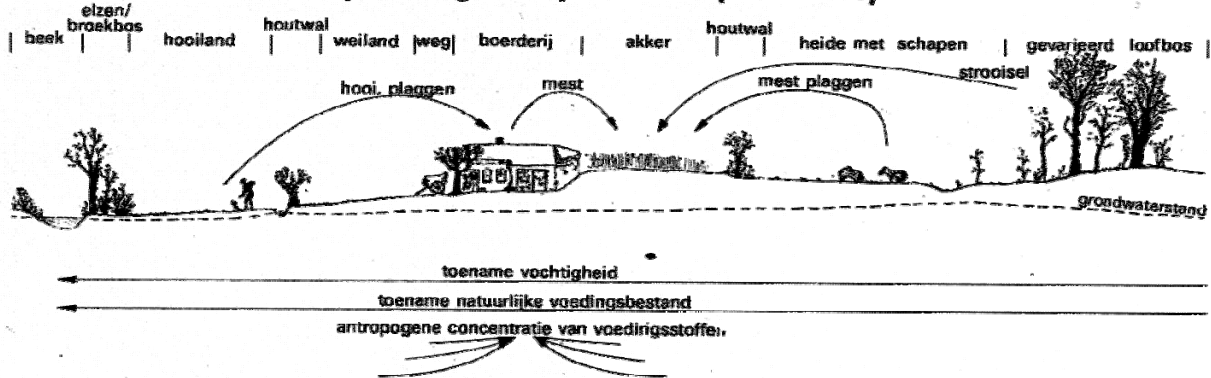
<sup>b</sup> Leeuwen (1971)

<sup>c</sup> Thünen (1921), Leeuwen (1973)

## Living between dry and wet

Farms and settlements on the high, infertile sandy soils were mostly situated along rivers and streams. On slopes between the lowest wet soils (known as 'green soils' in animal husbandry) and higher, drier soils ('common lands' used as arable land) the nitrogen cycle used in mixed husbandry gave the best chances of survival. Fights took place to secure these scarce sites, so that, once established there, the tendency was to concentrate, organise and defend the common land. The result was a village (*esdorp*, in Dutch) built around a village green or *brink*. This concentric village shape contrasts sharply with the 'linear village' (*lijndorp*, in Dutch) from which, along both sides, and at 90° angles to the village street, strips of fertile but wetter peat soils were colonised and drained. In the *dijkdorp*, farmsteads, also positioned at 90° angles to the street were built on the higher, drier ground at the side of the street, which followed the highest line of the dyke.

### a traditionele landschapsecologische processen (19e eeuw)



### b huidige landschapsecologische processen

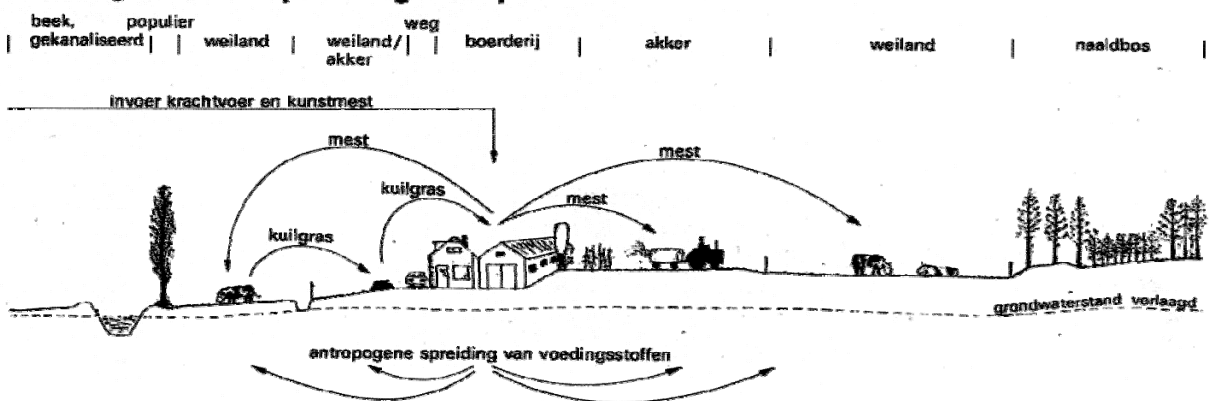


Fig. 866 Traditional and present-day ecological processes with respect to landscapes<sup>a</sup>

## Homogeneity by artificial manure

Modern agricultural methods, especially the discovery of artificial manures round about 1900 have changed these developments drastically from rare, infertile and thus species-rich biotopes into biotopes that are equally fertile overall and thus to biotopes that are predictable, but with few species.<sup>b</sup>

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<sup>a</sup> Atlas van Nederland Part 16:18

<sup>b</sup> Nederland heeft overigens van nature een aantal zeer voedselrijke gronden zoals rivierafzettingen, zeeklei en loss.

### Settlements on sandy grounds

In Fig. 867 Steegh (1985) designed a concept for the development of settlements on sandy ground

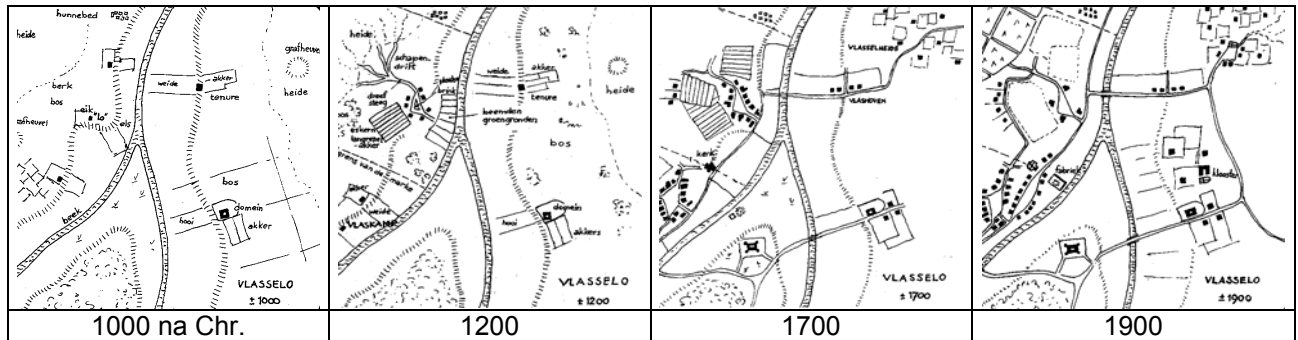


Fig. 867 An ideal-typical development of a settlement on sandy ground<sup>a</sup>

### Terp villages on Marine Clay areas

However, the oldest settlements that are still recognisable date from Roman times. Since those times, churches, farms, and sometimes settlements, in coastal areas, especially in Groningen and Friesland, have been built on raised mounds of earth (a *terp*). (Fig. 868).

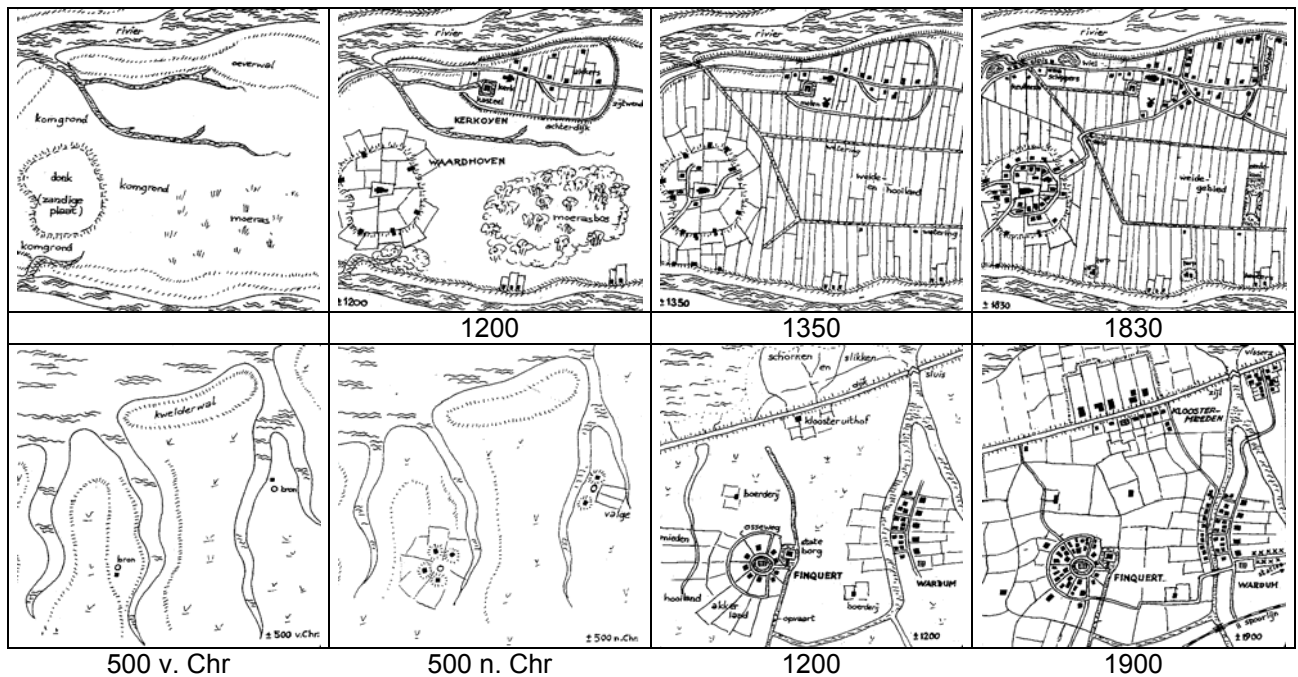


Fig. 868 The ideal-typical development of terp villages on Marine Clay areas<sup>b</sup>

<sup>a</sup> Steegh (1985)

<sup>b</sup> Steegh (1985)



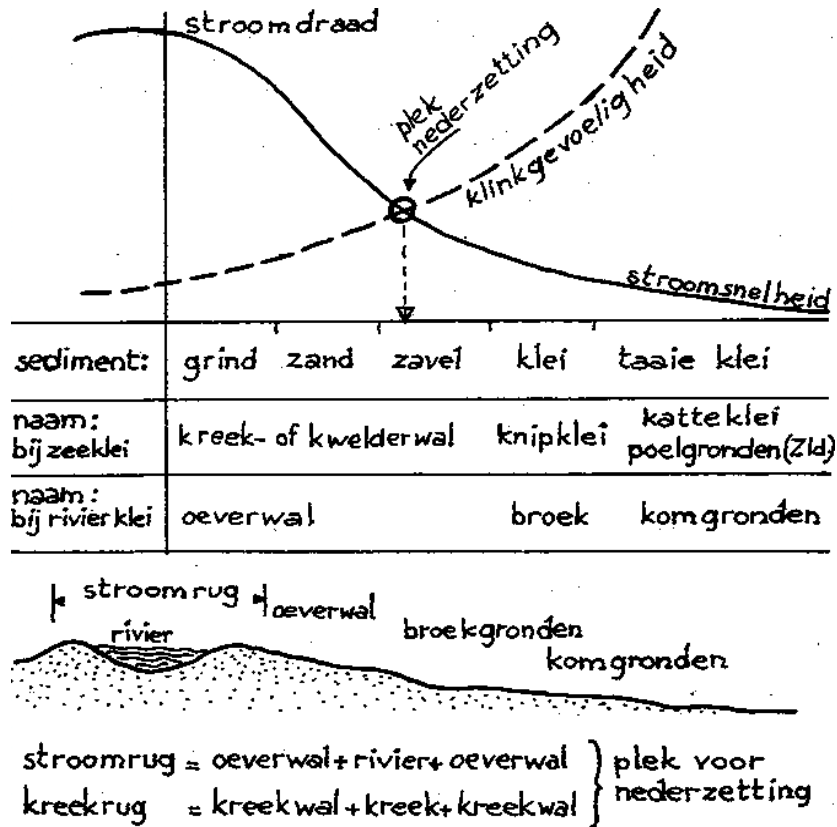


Fig. 869 Historical conditions for situating settlements along the water's edge<sup>a</sup>

### Roman settlements on the loess soils of South Limburg

The best preserved land surveying outlines from the Roman times are of the loess region of South Limburg: an underlying NW-SE and NE-SW grid of 707 x 707 metres or fractions of this. By creating lots of land by cutting it into blocks ('quadrangulation') in this rational way, Roman army veterans were rewarded with a villa as a retirement present. Steegh (1985) shows how these developed further in his ideal types 'Willerich', 'Willerrode' and 'Wilderbaan' (Fig. 870).

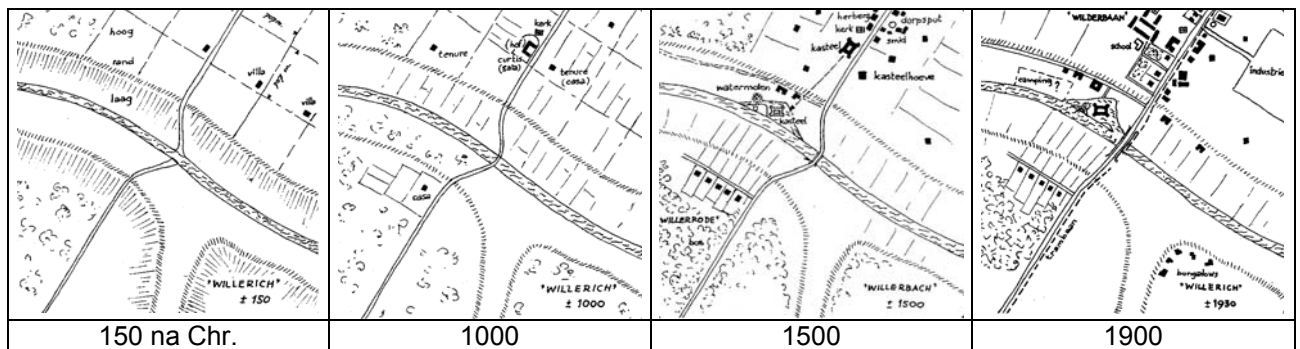


Fig. 870 The ideal typical development of settlements on the loess soils of South Limburg<sup>b</sup>

### Development of these settlements in feudal times around 1000 AD

Following the decay of the Roman Empire, the feudal court system began to use material from the most strategically situated villas (not too high, not too low, along a road crossing a nearby stream or river) to build a *curtis* or *sala* with an encircling wall in the form of a shield from which the farms

<sup>a</sup> Steegh (1985)

<sup>b</sup> Steegh (1985)

(*tenures* or *casae*) around were managed. The agrarian surplus was sent to the Lord of the Manor via the old Roman road. Since the time of Charlemagne, one tenth of the produce had to be given to the church, so the local manager built a church to collect these tythes himself and so that he only needed to maintain a priest. A smithy, brewery and safety-seeking small-holders formed a compact village centre and the *curtis* became the castle.

### Development of street villages around 1500 AD

Wetter areas allowed a larger number of village wells to be dug, so these villages had a more dispersed shape. A tenant farmer, whose land bordered on water, who later gained independence, would divide his land among his children into a larger number of units. In this way, a street village was formed, comprising easily defendable 'closed courtyards'. This is still a well-known type of farm building, even today, in the landscape of South Limburg. Millers' dwellings were added to the water mills and the lord of the castle built a new castle with gardens bordering the water, thereby displacing a number of farms that had occupied that land.

### Later developments

Sometimes, the Lord of the Manor systematically developed waste ground into a street village such as 'Willerrode'. The church remained on the site of the old castle in the centre of the village, where now the lord levied tolls, and an inn to accommodate the post stagecoach was built. After centuries of stagnation, the construction of a tramline to the coal mines in the vicinity brought about far-reaching changes. The inn became a centre for the mineworkers. The higher personnel built houses along the tramline and a mineworkers' colony, 'Wilderbaan', grew up with its own shops, a new church and a patrons' cloister, financed by the mine owners, with boys and girls schools. Supply industries established themselves there with workers' districts and bungalows built on sites which had the nicest views. On pages 161-162, Steegh (1985) names many villages where elements of ideal typical 'Willerich' are recognisable.

## 6.2.3 The last millennium

### The Netherlands about 1000 AD

Round about 1000 AD, the human population lived on *terps* (in Friesland), along the rivers, behind the dunes, and, in a more dispersed form, on the sandy soils.

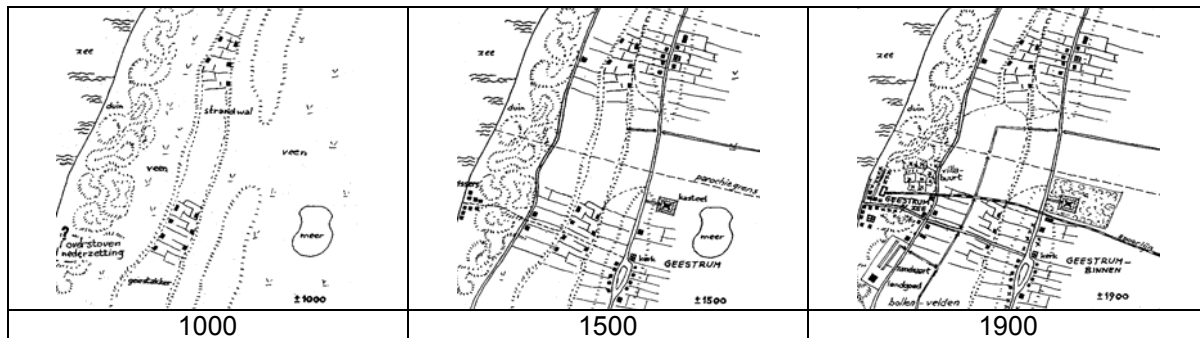


Fig. 871 The ideal typical development of settlements on sandy soils behind the dunes<sup>a</sup>

<sup>a</sup> Steegh (1985)

### After 1000 AD

From 1000 AD onwards it is people who have determined the appearance of the Netherlands. No longer they adapted their life to the country, they started to accommodate the country to their life (see Fig. 72, Fig. 872 and Fig. 873 are enlargements).

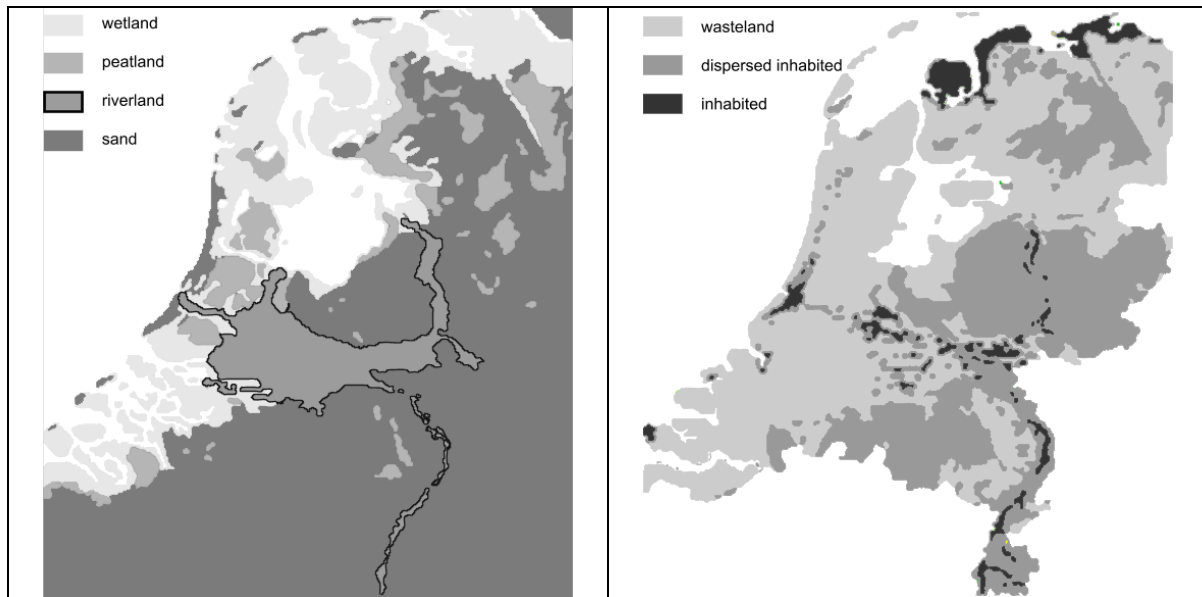


Fig. 872 Natural regions before 1000 AD

Fig. 873 Settlements in the Netherlands about 1000 AD<sup>a</sup>

### Rising sea level

After about 1000 AD, the sea advanced in the south of the country. The Delta waterways came into existence, but the free play of water and land was prevented by dams built by the rapidly growing population.

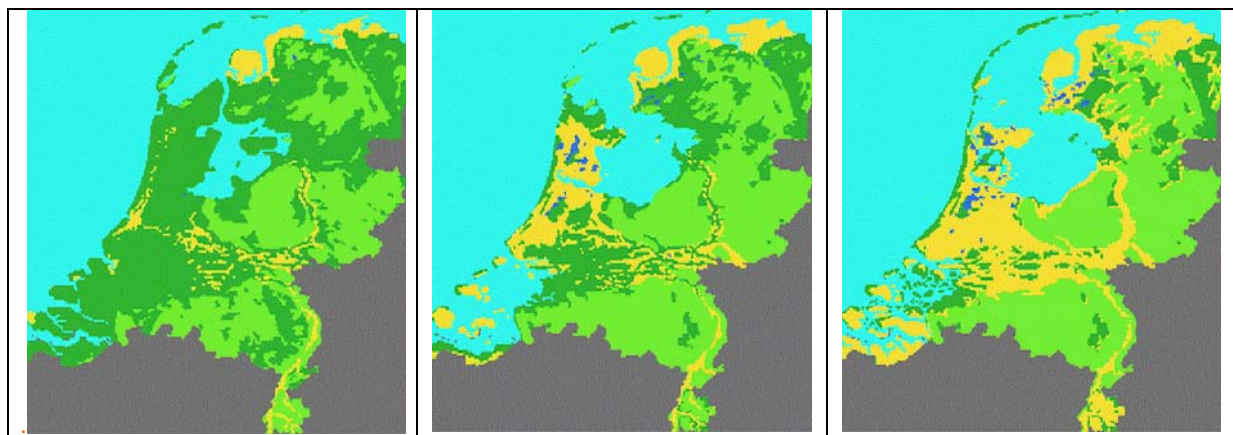


Fig. 874 (Fig. 873) 1000 AD.

Fig. 875 1100 AD

Fig. 876 1300<sup>b</sup>

### Land, no longer on loan from the Emperor: the end of feudalism

The ecological history of the low-lying lands is closely linked to reproduction, family links, illnesses and occupations, in short, to the ecology of the human species.

Count Dirk II married a descendant of Charlemagne and, in 987, was granted full ownership of his fiefdom in North Holland by Emperor Otto III. Dirk III extended the fiefdom to include wet lands in the

<sup>a</sup> University of Utrecht

<sup>b</sup> University of Utrecht

south. The only people who lived there at that time, were those living along the Old Rhine and at its mouth, at Leiden (Lede, water course Vries (1962)). In 1063, Dirk V was the first to adopt the title Count of Holland, but it was not until approximately 1100 that the name Holland came to be used for the whole county. What happened during that century?

**Making your own land**

There is evidence of an enormous expansion in agriculture and settlement in the centuries immediately subsequent to 1000 AD. In particular, people learnt how to reclaim and cultivate peat bog (fen).

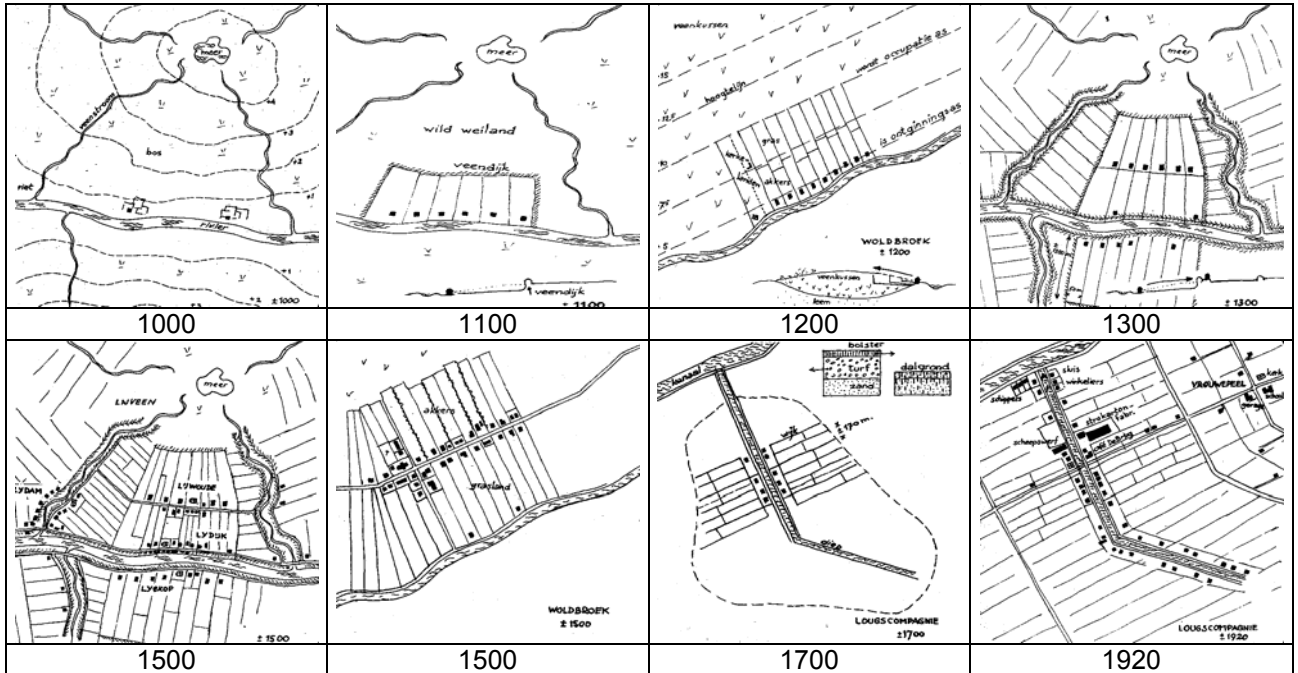


Fig. 877 The ideal typical development of old and new peat settlements<sup>a</sup>

**Colonisation**

In the course of a century, the Netherlands was far-reachingly colonised. There were a number of small towns at this time. Around 1300, these towns began to grow. There was also growth on the sandy grounds, and forests started to disappear. The sea retreated in some places and advanced in others. By about 1300, there was hardly any 'nature' left any more.

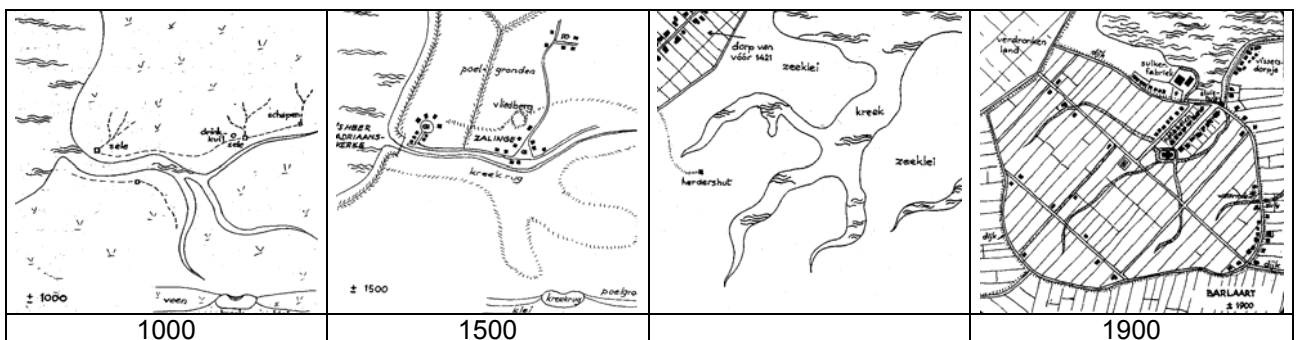


Fig. 878 The ideal typical development of new settlements on the clay soils<sup>b</sup>

<sup>a</sup> Steegh (1985)  
<sup>b</sup> Steegh (1985)

The reconstruction made by the University of Utrecht for NNAO (see Fig. 72) shows an unmatched colonisation of these low-lying lands. The first dateable information about the participation of Dutch farmers in the colonisation of peat areas in eastern Germany (Hollerbroek) appeared in 1113. These farmers were especially welcome because of their skills in draining low-lying areas.

### Democratic water boards

Dirk VII's brother, Count Willem I, had a grandson, Floris V, 'The blokes' God', who was married with Beatrix. By founding democratic water boards, he prioritised agrarian development that was based on the growth of population resulting from draining the land. He met with resistance from feudal aristocracy, such as Gijsbrecht van Amstel, who were becoming impoverished, which, in 1296, cost him his life.

### Growing wealth replacing taxes by toll

Towns, and particularly Dordrecht, were centres for the toll system of Holland and needed to extend the trading basis on which they were founded. Most of them were granted their town charter in the 13th century. This was the century during which the influence of Holland grew to such an extent that Count Willem II became the Holy Roman King of Germany with his polder model. The Pope was making preparations to crown him as emperor when he was beaten to death on the slippery Friesian ice. However, his grand nephew, Willem III, was able to marry the daughter of the French king and arrange marriages for his own daughters to the English king, Edward III and the Bavarian emperor, Ludwig.

### Feudal interference

However, that last-mentioned strategy led to renewed feudal interference. The emperor went fishing for the fattened cod that Otto III had allowed to slip off his hook (the Hook and Cod Disputes (*de Hoekse en Kabeljauwse Twisten*<sup>a</sup>)). Struggling to free themselves from the aristocratic–feudal 'Hooks' were the 'Cod'-supporting farmers and citizens, such as those of Delft.

### Ecological influences on trade economy

The County of Holland remained relatively free from the pest epidemics that had brought about a demographic reversal in Flanders and the towns of the Hanseatic League. Bruges partly lost its cloth trade to Holland (Leiden). The movement of herring shoals from the Baltic Sea to the North Sea, and herring gutting skills that had been discovered in the mean time, gave fishermen there an ecological advantage. They sailed to wool-rich England and gradually took over the freight trade. After 1500, partly due to the St. Elizabeth flood in 1421, Dordrecht was forced to relinquish its position as main port to Delft, Rotterdam and Amsterdam. After the Treaty of Utrecht in 1475, the towns of Holland took over the Baltic trade from the Hanse as Jansen (1995) describes. Counts became Stadtholders. For one more century Holland accepted a foreign head-of-state before starting to fight for definitive freedom.

### Crucial waterways

The making of dykes, widespread partition of land and draining in Holland encouraged population growth. This caused the peat areas to settle and allowed little by way of occupation other than animal husbandry, fishing and shipping. For this reason, the Hollanders were dependent on grain from the regions around the Baltic Sea. Fortunately, the Hanse preferred to transport their Baltic goods via the, in the mean time deepened, waterways of Holland, to their entrepot in Bruges, than over the dangerous North Sea. In exchange for the much reduced damage to their ships by using this route, the Hanseatic League paid tolls to the Counts of Holland.

### Tax relief, Republic and Public Works

This income for the Counts brought tax relief to the farmers. As they had made their own land, they no longer saw themselves as being bound by the requirements of the feudal system (Jansen (1965)). Uneven economic growth reduced any natural areas that still existed to a few areas of blanket bog. The low-lying peat bogs were used as fuel, and winds exposed the underlying Marine Clay. The Mast Forest in Breda was planted to provide shipping with masts. However, the impulse of Golden Age slowed down when people began to live off their private means instead of investing. This resulted in

<sup>a</sup> Jong, Taeke M. de (2004) *Schaalgeleding bij Hoeken en Kabeljauwen* (Zoetermeer) MESO <http://team.bk.tudelft.nl/> > Publications 2004



the wet land of Woud (1987)<sup>a</sup> being left behind and caused the French to establish a department of Public Works in 1798.

### The first Republic since Rome: The United States of The Netherlands

Then, in 1585, Antwerp capitulated to the Spaniards, led by the Duke of Parma. Antwerp, with its multicultural way of life and its urban hinterland, had become the trading centre of the 16th century world. It was the northern entrepot for products from countries around the Indian Ocean as Bouman (1979) describes. This is where modern banking and economic individualism bundled into companies began. During the following four years, almost half (approx. 38,000 people) of its largely Protestant inhabitants fled to the north as Israel (1995) describes, thereby laying the *laissez faire* foundations of the partly immigrant-inhabited metropole of Holland and its trade emperium. The French did not help the young Republic gain acceptance and sovereignty, as the Orange's continued to hope, but they did help by diverting the attention of Philip II, and thus the Duke of Parma, southwards. That gave Maurits opportunities and Van Oldenbarneveld succeeded in bringing competing parties together to form the VOC. That Maurits continued to believe in predestination, and thus in aristocracy, cost Van Oldenbarneveld his life.

### The early urbanisation of Holland

Around 1550: more than half of the population of Holland lived in towns that had grown up for the purpose of conducting trade.

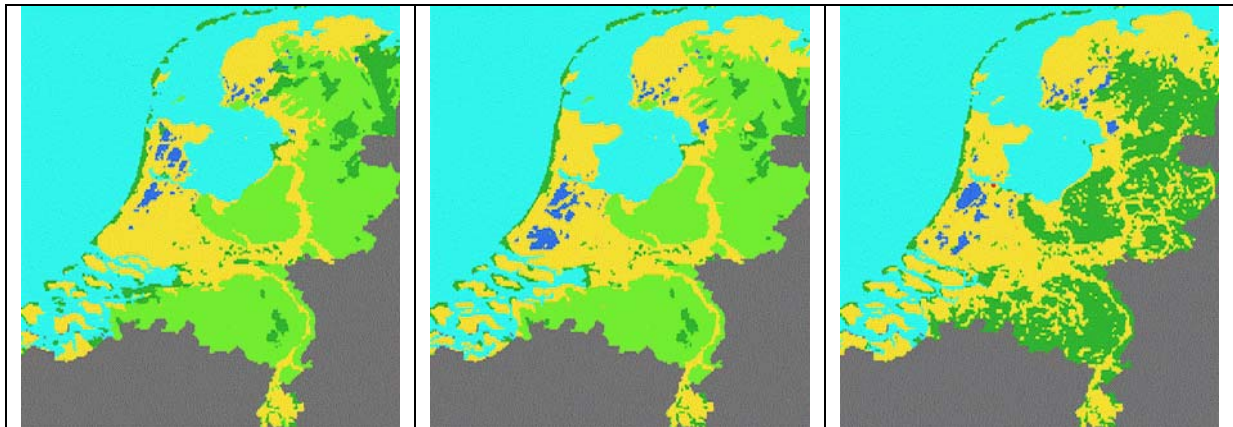


Fig. 879 1550

Fig. 880 1675

Fig. 881 1800<sup>b</sup>

### The Golden Age and the economic decline that followed.

Around 1675: the towns in the west had grown fast. A network of tow-barge canals had come into existence.<sup>15</sup> Development on the sandy soils had come to a halt.

Around 1800: following the impoldering of North Holland, large areas of blanket bog were reclaimed. More dykes were built. From a hydraulic point of view, the land was in a deplorable state.<sup>16</sup>

### Recovering land and nature

This is how the relatively recent nature of the Netherlands, has come into existence. It is so different from anywhere else in Europe that a separate legend unit is needed to register it on the European nature map of Bohn<sup>c</sup> (see Fig. 860). The task of impoldering the land was completed with the use of the steam engine. To work on the remaining 'waste grounds', the Heide- and Grondmij were established at the end of the 19th century. These relatively new natural areas were later reduced again to provide employment during the 1930s, when unemployment levels were so high.

<sup>a</sup> Woud, A. v. d. (1987). *Het lege land. De Ruimtelijke Orde van Nederland 1798-1848 (Proefschrift)*. (Amsterdam) Meulenhoff informatief.

<sup>b</sup> University of Utrecht

<sup>c</sup> Bohn, U., G. Gollub, et al., Eds. (2000) *Map of the Natural Vegetation of Europe scale 1: 2.5 million* BN Bundesamt für Naturschutz (Bonn) Federal Agency for Nature Conservation.

### Artificial fertilisers

Artificial fertilisers were discovered round about 1900. Since then, fertilising areas of soils with low-mineral content has favoured rapidly maturing crops, to the detriment of slowly maturing specialist species. Animal husbandry, drainage and atmospheric deposition have all contributed to this process. Just as it is easier to dissolve sugar in coffee than to take it out again, so will much time be needed before these levels of fertilisation are cut down. For this reason, it is not just rarity expressed in kilometres that counts, but also (ir)replaceability in years. One can use the product of these two values to gauge the value of natural areas against the rarity and replaceability of human artifacts.

### Recent centuries

*Around 1850:* the growth of industry in Twente and in North Brabant. Impoldering of lakes caused by peat exploitation in the western fenlands. The digging out the peat of the blanket bogs of the higher eastern areas.

*Around 1900:* western areas were still the most urbanised. The population of Amsterdam exceeded 500,000. The railway network was completed.

*Around 1930:* industrialisation on the sandy soils reached a peak. Conurbations began to form everywhere.

*Around 1960:* land reclamation and the Delta works, in addition to large urban and industrial expansion.

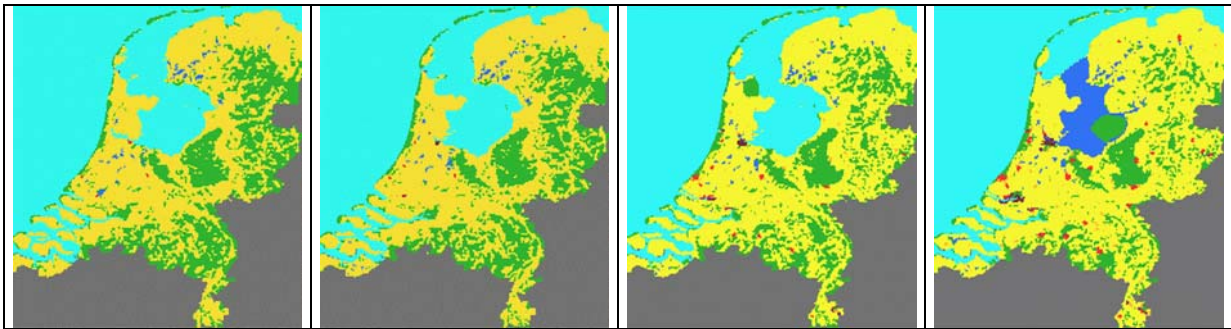


Fig. 882 1850

Fig. 883 1900

Fig. 884 1930

Fig. 885 1960<sup>a</sup>

In the second half of the 19th century, two cultivation associations, the Heidemij and the Grontmij were established to bring new nature areas under cultivation again, that had originated since the Golden Age.

### Land consolidation and nature management

These associations played an important role in land consolidation (ruilverkaveling).

<sup>a</sup> University of Utrecht



Fig. 886 Before land consolidation



Fig. 887 After land consolidation<sup>a</sup>

An interest in nature conservation and management arose at the beginning of the 1900s. Since 1970, there has been an increasing interest in managing nature and in introducing policies to conserve nature by consolidating land. At present, land consolidation is also an instrument to nature conservancy policy-makers (in riverine and peat bog areas). Road and air transport play a large new role, but a threatened environment requires a place of its own, too.

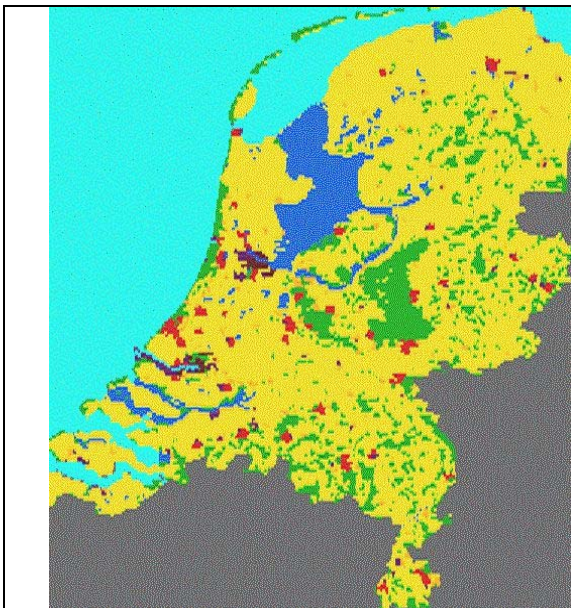


Fig. 888 The Netherlands in 1989

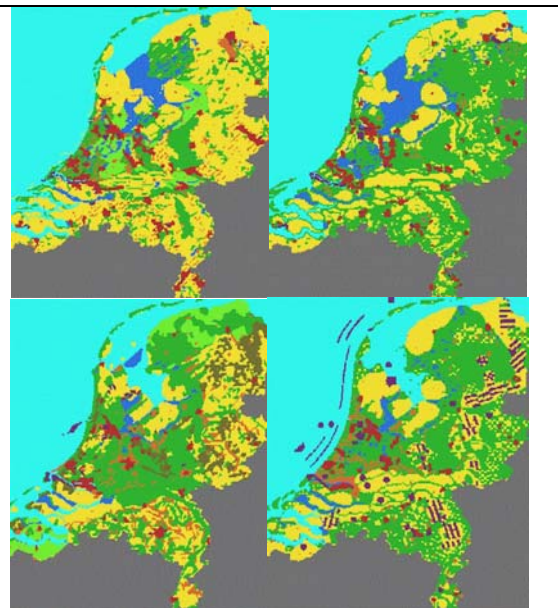


Fig. 889 Ideas for 2050<sup>b</sup>

<sup>a</sup> Wolters-Noordhof (1981)

<sup>b</sup> NNAO (1987)



## 6.2.4 Reading topographical maps (Visser)

### Map images of higher grounds in The Netherlands





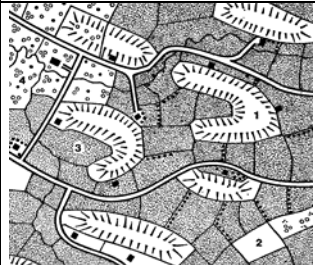





			
<p>South Limburg</p> <ol style="list-style-type: none"> <li>1. edge of valley</li> <li>2. stream</li> <li>3. wooded side of valley</li> <li>4. settlement</li> <li>5. arable land</li> <li>6. grassland with wooded banks</li> </ol>	<p>North-Limburg</p> <ol style="list-style-type: none"> <li>1. arable land on a fluvial terrace</li> <li>2. old fluvial dunes</li> <li>3. hedged landscape</li> <li>4. old fluvial beds</li> <li>5. river</li> <li>6. settlement</li> </ol>	<p>North -Brabant</p> <ol style="list-style-type: none"> <li>1. dune ridge (duinrug)</li> <li>2. small peat bog/fen mere</li> <li>3. stream</li> <li>4. woodland along a stream</li> <li>5. settlement on old arable land</li> <li>6. fluvial- or water meadows</li> <li>7. cultivated land outside the valley of a stream</li> <li>8. planted forest</li> </ol>	<p>Central Slenk</p> <ol style="list-style-type: none"> <li>1. road</li> <li>2. grassland</li> <li>3. arable land</li> <li>4. remains of a woodland</li> </ol>
			
<p>Wind-borne sand dunes</p> <ol style="list-style-type: none"> <li>1. parabolic-shaped sand dune</li> <li>2. small arable field on flatter terrain</li> <li>3. grassland between hill ridges</li> <li>4. woods on a country estate</li> </ol>	<p>Achterhoek</p> <ol style="list-style-type: none"> <li>1. hill with old arable land</li> <li>2. little field on plain surface</li> <li>3. grassland of lower grounds</li> <li>4. little wood</li> </ol>	<p>heathland reclamation</p> <ol style="list-style-type: none"> <li>1. heath</li> <li>2. field</li> <li>3. grassland</li> <li>4. wood</li> </ol>	
			
<p>Lateral moraines of East-Twente</p> <ol style="list-style-type: none"> <li>1. contour of lateral moraines (stuwwal)</li> <li>2. old farmland on flank of lateral moraine</li> <li>3. grassland surrounded by wood on moist grounds</li> <li>4. settlement</li> <li>5. wet woods (broekbos)</li> </ol>	<p>Lateral moraines of West Twente</p> <ol style="list-style-type: none"> <li>1. contour of lateral moraine (stuwwal)</li> <li>2. meltwater ridge</li> <li>3. settlement</li> <li>4. old farmland on Eastern flank of lateral moraine</li> <li>5. grassland on moist plains</li> <li>6. heath</li> <li>7. planted coniferous wood</li> </ol>	<p>Ash trees along the valley of a stream</p> <ol style="list-style-type: none"> <li>1. field (es)</li> <li>2. stream valley (beekdal)</li> <li>3. tableland</li> </ol>	

Fig. 890 Landscape elements on maps of higher grounds in The Netherlands<sup>a</sup>

<sup>a</sup> Visscher (1972)

**Map images of lower grounds in The Netherlands**

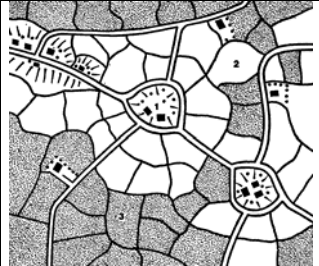
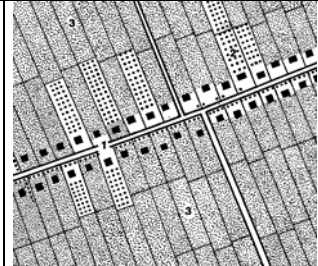
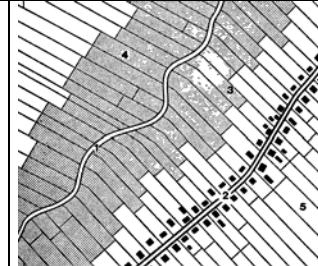




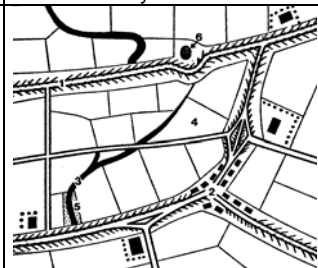

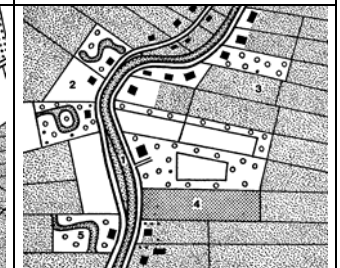
			
<p>terp landscape</p> <ol style="list-style-type: none"> <li>1. terp with buildings</li> <li>2. field</li> <li>3. grassland</li> </ol>	<p>Parcelled landscape of West Friesland elongated lots</p> <ol style="list-style-type: none"> <li>1. regional village (streekdorp)</li> <li>2. orchard</li> <li>3. grassland</li> </ol>	<p>Parcelled landscape of the northern Netherlands (slagenlandschap)</p> <ol style="list-style-type: none"> <li>1. stream</li> <li>2. road village (wegdorp)</li> <li>3. lot border</li> <li>4. grassland</li> <li>5. farmland (bouwland)</li> </ol>	
			
<p>Water collection on dune landscapes</p> <ol style="list-style-type: none"> <li>1. dune ridge</li> <li>2. lower part of dune area</li> <li>3. digged perpendicular watercourse</li> <li>4. small wood dyke (houtkade) bordering village area</li> <li>5. surface dune relic (donk)</li> </ol>	<p>Beach banks between Leiden and Haarlem (strandwal)</p> <ol style="list-style-type: none"> <li>1. road village</li> <li>2. country estate on ridge</li> <li>3. wet wood on sea side valley</li> <li>4. canal for shipping digged sand</li> <li>5. bulb field on digged part of sea side ridge</li> <li>6. grassland in moisty sea side valley</li> </ol>	<p>peat bog area with peat stream</p> <ol style="list-style-type: none"> <li>1. stream with regional village</li> <li>2. grassland</li> <li>3. digged perpendicular watercourse</li> <li>4. small wood dyke bordering village area</li> <li>5. surface dune relics</li> </ol>	
			
<p>Nature areas beyond the dyke(s) in South West Netherlands</p> <ol style="list-style-type: none"> <li>1. salt marsh (schor)</li> <li>2. mud flat (slik)</li> <li>3. sea dyke</li> <li>4. farmland</li> </ol>	<p>The dyke system of SW Netherlands</p> <ol style="list-style-type: none"> <li>1. dyke planted with trees</li> <li>2. dyke village</li> <li>3. creek relic</li> <li>4. farmland</li> <li>5. grassland on creek bed</li> <li>6. pool as relic of bursting of the dike (wiel)</li> </ol>	<p>Fluvial landscape</p> <ol style="list-style-type: none"> <li>1. abandoned river bed</li> <li>2. settlement</li> <li>3. raised old arable land</li> <li>4. country estate</li> <li>5. orchard</li> <li>6. field</li> <li>7. grassland</li> </ol>	<p>Country estates of West Utrecht</p> <ol style="list-style-type: none"> <li>1. river</li> <li>2. field</li> <li>3. grassland</li> <li>4. orchard</li> <li>5. country estate</li> </ol>

Fig. 891 Landscape elements on maps of lower grounds in The Netherlands<sup>a</sup>

<sup>a</sup> Visscher (1972)

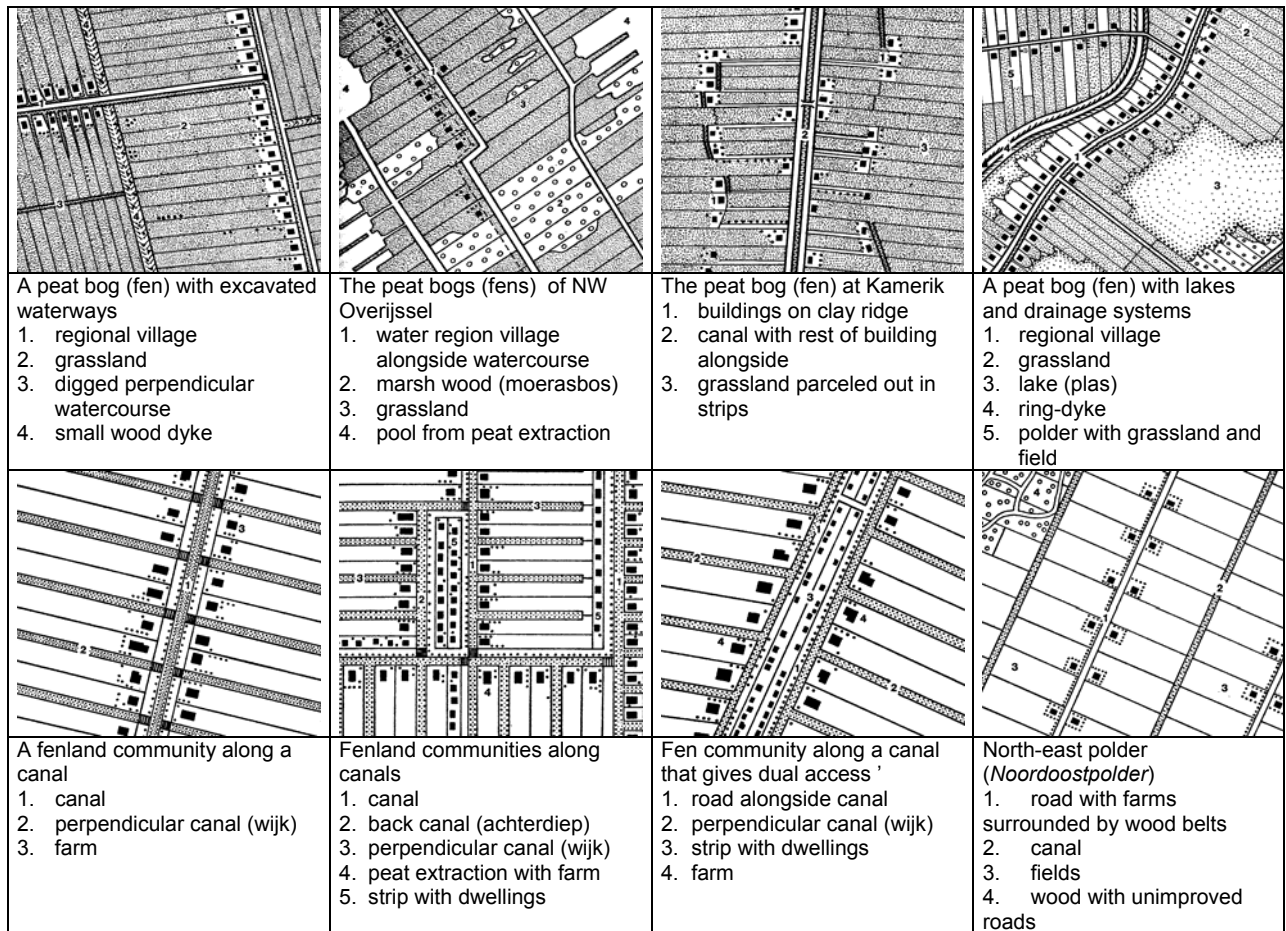


Fig. 892 More recent landscape elements on maps of lower grounds in The Netherlands<sup>a</sup>

<sup>a</sup> Visscher (1972)



## 6.3 Density

### 6.3.1 Global densities<sub>10 000km</sub>

The Earth's surface counts 511 185 932 km<sup>2</sup> and 6 501 085 722 humans (estimation march 3<sup>rd</sup> 2006)<sup>a</sup>. So, the gross population-density is nearly 13 inhabitants per km<sup>2</sup> (nearly 8 ha per person).

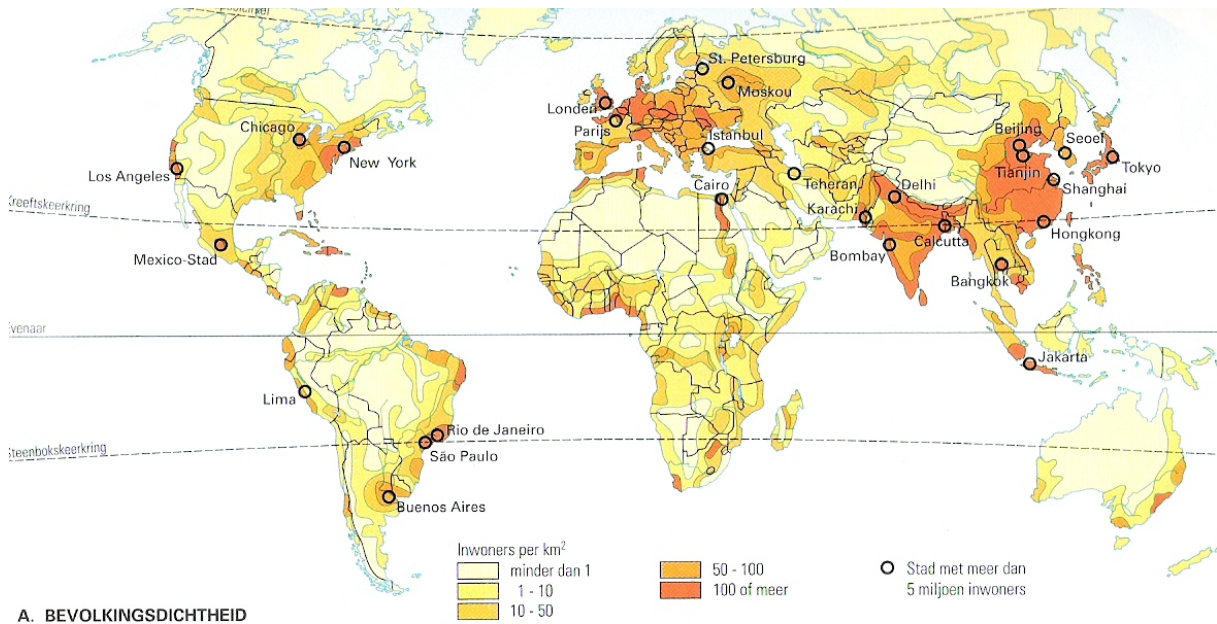


Fig. 893 Global density from <1 until >100 inhabitants per km<sup>2</sup> <sup>b</sup>

However, people usually do not live in the sea. The net population-density *on land* is about 44 inhabitants per km<sup>2</sup> (about 2 ha land per person), because about 29% of the Earth's surface is land. So, the measure of density is most dependent on the kind of surface you take into account.

### 6.3.2 Gross and net density

Having excluded the oceans as tare surface to measure globally net human density on the Earth's surface, the question arises if, on continental level, you should take all land into account, including the arctic areas, mountains, deserts, forests (continentally gross), or only the habitable land (continentally net). After all, for application in urban design, the aim is to compare inhabited areas. If so, what is habitable land? Looking at Fig. 893, many areas count less than 1 inhabitant per km<sup>2</sup>, mostly useless for agriculture and sustainable settlement. We can call that 'tare surface' on a continental level (see Fig. 894). The remaining 'net surface' with a higher ('net') density, usable for any form of settlement, we can call 'habitable land'.

<b>Higher level</b>	<b>gross</b>	
	<b>net</b>	<b>tare</b>
<b>Lower level</b>	<b>gross</b>	
	<b>net</b>	<b>tare</b>

Fig. 894 Net, tare and gross on different levels of scale

However, most of these habitable surfaces are actually used for agriculture, some for urban concentrations. These urban areas sometimes count more than 5000 inhabitants per km<sup>2</sup>

<sup>a</sup> <http://www.census.gov/ipc/www/world.html>

<sup>b</sup> Bosatlas(1996)

(50 inhabitants per ha). Urban areas are most interesting to us if we would like to compare metropolises, conurbations, towns, districts, neighbourhoods and so on. Going on systematically with the interval boundaries 1-10-50-100 into 500-1000-5000 in the legend of Fig. 893, the legend units of highest density would become invisible on the scale of the map. Moreover, the intervals are not equal. That means the shown pattern is accidental. The pattern is changing by the choice of intervals. They are chosen to produce the most striking pattern, but if population grows, the chosen intervals may become insufficient to see any pattern. Moreover, on an urban scale we are most interested in subdivisions between 1000 and 10000. So, changing scale to visualise details we have to skip the lowest densities calling them 'tare'.

### 6.3.3 A binary legend: net and tare surface

On any level of scale from the gross surface you can subtract relatively unused areas as 'tare surface', resulting in gross and net density. On a lower level of scale the net surface becomes gross surface from which you can subtract other kinds of tare. So, to compare densities properly, you have to distinguish levels of scale, each with its own legend (see Fig. 895) to determine gross and net density.

Name frame	m nominal radius		binary legend	
	frame	grain	net	tare
Global	10 000 000	1 000 000	continents	oceans
Continental	3 000 000	300 000	habitable lands	lakes and waste lands
Subcontinental	1 000 000	100 000	urbanised areas	rural areas
National	300 000	30 000	urban networks	landscapes
Subnationaal	100 000	10 000	urban regions	landscape parks
Regional	30 000	3 000	conurbations	town landscapes
Subregional	10 000	1 000	towns, quarters	town parks
Urban, local	3 000	300	districts, villages	district parks
District	1 000	100	neighbourhoods, hamlets	neighbourhood parks
Neighbourhood	300	30	ensembles	dispersed greenery
Ensemble	100	10	lots	opening up (access) area
Lot	30	3	houses	gardens, patios
Dwelling	10	1	living rooms, studies, bedrooms	inaccessible space, wet rooms, circulation and storage spaces
Room	3	0,3	sitting areas, dinettes, beds	walking area, cupboards, closets, windowsills
Place	1	0,1	action-surrounding space	commodities

Fig. 895 Fifteen levels of scale to distinguish 15 different kinds of density

### 6.3.4 (Sub)continental densities<sub>3 000 and 1 000km</sub>

On a European level of scale, adding an extra interval boundary of 200 inhabitants per km<sup>2</sup>, you can observe a central urbanised axis of more than 200, surrounded by 'rural' areas of less than 200 inhabitants per km<sup>2</sup>. However, at a regular distance within these 'rural' areas, there are some conurbations (London, Paris, Lyon, Milan, Munich, Prague, Berlin, Hamburg; see Fig. 897). Some of these do have the highest European density measured within a local radius of 30km.

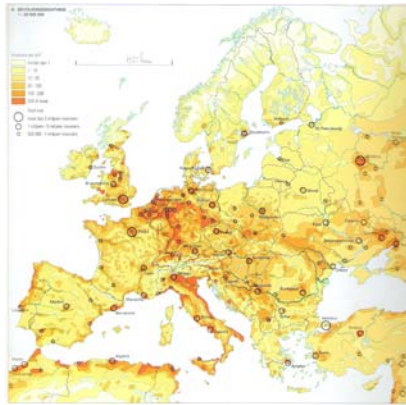


Fig. 896 Continental densities

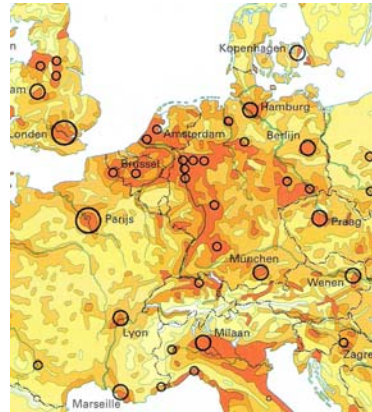


Fig. 897 Subcontinental densities



Fig. 898 Legend<sup>a</sup>

So, there are not only different *densities*, but also different *distributions*, producing patterns interesting from a viewpoint of design.

### 6.3.5 National densities and distributions<sub>300km</sub>

#### Land use, the reciproque of population density

The Netherlands as a whole counts more than 42000km<sup>2</sup> (sea excluded) and 16300000 inhabitants, that is about 390 inhabitants per km<sup>2</sup> (about 4 inhabitants per ha) with extremes ranging from 0 to 20 000 inhabitants per km<sup>2</sup> if you take smaller areas into account.

The reciproque of population density is land use. The advantage of a land-use unit is that different destinations of use can be discerned. In the Netherlands, the land use is about 2700 m<sup>2</sup> per inhabitant, roughly divided as 1500 m<sup>2</sup> of agrarian land per inhabitant, 500m<sup>2</sup> of water, 300 m<sup>2</sup> of nature areas and forest, 300 m<sup>2</sup> of urban areas and infrastructure, 100m<sup>2</sup> industry and recreation.<sup>308</sup>

#### Residential area, part of urban area

Of this 300m<sup>2</sup> urban area, only about 160m<sup>2</sup> are 'residential areas'<sup>309</sup>. According to CBS's definition of ground statistics<sup>b</sup>, these are homes with green areas, hardened surfaces and primary facilities, such

<sup>a</sup> Bosatlas(1996)

<sup>b</sup> **Dwelling area** Spaces that are primarily meant for dwelling, we count as dwelling areas including primary services like shops, schools for pre-school kindergarten and primary schools, offices of banks but also green spaces, streets, parking places, urban canals less than 6 meter wide, premises, gardens, grass plots and playgrounds. In case dwelling areas are located in forests, the whole area is marked as dwelling area only in case a street structure can be perceived.

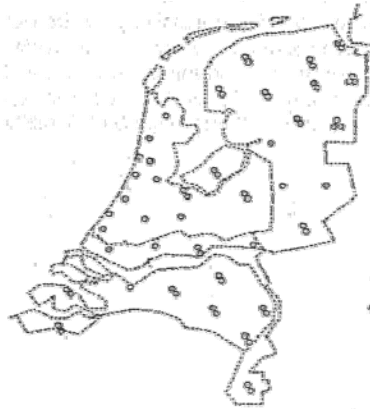
Ribbon development of mainly non-agrarian dwellings is counted as dwelling area if the distance between the houses is less than 50 meters with a minimum of five dwellings.

In case of building blocks, the relative distance between the blocks may be a maximum of 100 meters. Included in the dwelling area are also caravan camps (excluding wrecked cars storage, houseboat harbours, warden-assisted flats, student housing, housing and flats for hospital staff and student housing, homes for the elderly. Only realised dwellings are counted as dwelling area.

**Socio-cultural facilities** Here is included all educational facilities (excluding schools for pre-school kindergarten and primary schools that belong to dwelling areas), boarding schools, conference centres, hospitals, sanatoriums, nursing homes, psychiatric hospitals,

institutions for the mentally handicapped, homes for the elderly, churches, monasteries, museums (also for castles open to the public), but excluding open-air museums, theatres, cinema's, concert halls, conference centres, cultural centres, community centres, club buildings, youth associations and sheltered workshops. Also counted to these facilities are the accompanying facilities like parking lots and gardens. Forests belonging to these facilities are only counted as such in case they are 1 ha or larger.

as local shops, schools for pre-school and primary education, as well as other residential facilities such as caravan camps, house-boat harbours, service flats, etc.<sup>310</sup>



*in dots of 100 m<sup>2</sup> per inhabitant.*

Fig. 899 Residential area per COROP area

Fig. 899 shows the distribution of this residential part of the urban area, divided over 40 statistical (COROP) areas, expressed in the absolute sense and per inhabitant according to CBS (1994) .

The residential area per inhabitant varies in space. In the west of the Netherlands, an average of about 100 square metres of residential area is available per inhabitant; in East Groningen, about 300 m<sup>2</sup>; and in a number of other places between those two extremes, about approx. 200 m<sup>2</sup> per inhabitant<sup>311</sup> .

So, 'norms' for the number of m<sup>2</sup> of residential area per inhabitant differ regionally. That also applies for other facilities, such as (daily) recreational areas or drinking water basins. Apart from variation in space, land-use norms also show a variation in time: they change.

So, the use of Planological Index Numbers for the amount of space needed for facilities is relativised by these spatial and temporal variations.<sup>312</sup>

### Population density divided by the number of occupants per household

If one divides the density of inhabitants by the local average number of occupants per household, then one arrives at the local density of homes<sup>313</sup>. However, since WW2, the number of people per household, especially in the towns, has dropped from about 5 to 2.5<sup>314</sup>; and this number continues to fall. This, by the way, was the main reason for scarcity of housing in the later post-war period, and for the urban explosion after 1960. There are not only great variations in time in the number of people per household, but also large regional differences. The number of people per household is the lowest in the Randstad and here the numbers have decreased the most rapidly in the last 50 years. In Fig. 701, the urban areas in the Randstad in 1965 are compared with those in 1995. During this period, the Randstad hardly grew in numbers of inhabitants (from 5.3 million to 6.1 million). The extension of urban area was caused, among other things, by fewer people living in one household (family dilution).

### Floor space is more reliable than the number of houses

The objects to be counted should be equal. That is why the floor surface, to be measured in m<sup>2</sup> is much better a measure to get a ratio of climatized volume per earth area than the number of houses of different size (as often done). For example the Dutch housing policy Secretary of State 1973-1977 Van Dam approximately doubled the number of houses produced per year in the Netherlands by halving their floor surface. Coincidentally the demand of one person households for smaller houses was increasing. It was a great political succes, but few politicians realised that Van Dam did not increase the newly built floor surface (and building effort) substantially.

### Drawing the real measure dot distribution

The regional spatial effect becomes obvious when you redraw the map in real measure units of 100,000 and 10,000 inhabitants, counting 300m<sup>2</sup> per inhabitant (the approximate overall urban spatial use mentioned on page 502). In Fig. 701 these are shown as circles with a radius of 3 and 1 km, respectively. Read: '3 km radius' or '3 km in the round' and say: 'town'. Read: '1 km radius' and say 'district' if part of a town or 'village' if separate. If circles overlap, then one has to conclude that the urban density is higher than the average national density. If there are about ten 3km circles (1 million people) within a radius of 10 km, then you can talk of 'conurbations' and draw them as one circle of 10km.

### Growing conurbations by growing land use

According to this representation, the old situation of 1965 (Fig. 701) was characterised by three large and three small conurbations and only a few small (separate) towns. In 1990, the first thing that strikes one is the dilution of households: the conurbations had grown, sometimes even losing inhabitants into suburban settlements. One can call this form of expansion 'deglomeration'. This influences not only

the built-up areas drastically, but also the open areas in between. As soon as urban areas are no longer surrounded by rural areas of the same order of size as the urban area, a reversal in the image of the urban area occurs: the town is no longer situated in the countryside, but the countryside is now enters the town, a reversal pointed out by Tummers and Tummers (1997, see Fig. 787)

### Fragmentation of urban and rural areas

The fragmentation of urban and rural areas on different scale levels can be visualised in the legend in Fig. 769.<sup>315</sup> The figures shown in this table are not absolute. They can be interpreted with a tolerance of up to the previous or the next figure shown in that column. The legend units shown in red are represented as circles with a size that reflects the present average urban spatial use in the Netherlands of approx. 300 m<sup>2</sup> per person: 160 m<sup>2</sup> urban residential area, 60m<sup>2</sup> working area<sup>a</sup> and 80 m<sup>2</sup> of infrastructure (a part of it lies outside the built-up area and therefore does not need to be regarded as an urban area).

### Dry and wet infrastructure

For linear-shaped legend elements, a similar sort of semi-logarithmic series is possible. Fig. 492 shows nine levels of access.<sup>316</sup> Something similar is possible for drainage (Fig. 491). 'Without information to the contrary', in the (former) low peat areas, the legend units are considered to be completely filled with the named networks. In clay areas the lowest orders with higher network densities disappear. In dunes, nature conservancy areas, and higher sandy grounds, even more lower orders disappear. In urban areas, ditches and drainage channels disappear. Their function is taken over by a relatively fine-meshed underground drainage network.<sup>317</sup>

### Distinguish existing and future population

Fig. 769 shows a legend for representing the dispersion patterns in a stylised manner on a regional scale. On the basis of this, regions can be compared. The estimated economic, cultural and/or managerial efforts needed to realise the areas drawn into the design can be indicated using different thicknesses of lines. The thinnest lines represent existing areas. This more or less reflects the importance of the element in the design. At the same time, this provides an elegant way of distinguishing existing areas from the new ones proposed (the 'planning layer'). Apart from this, the legends are literally 'open' in the sense that the circular legend units can still be coloured with functional accents or identities. For the time being, the circles can be seen as 'little magnifying glasses' which conceal unfilled-in details of towns, villages, hamlets, landscaped parks, urban

<sup>a</sup> **Extraction of minerals** Here are included all grounds that are used for the extraction of minerals both opencast mining and mining industry, as soon as the exploratory drilling and exploitation has started. Included are also all buildings, depository spaces for minerals and the residues and leftovers like the mountains of residues from mines, except if these are planted with forest and 1 ha or larger. Quarries and open-pit mining often lead to large holes, are also counted to this category as long it still is the main function. As soon as on part of the grounds the main function changes, it is counted to that category like water after sand and gravel extraction that is used for recreation as main type of land use, daytrip facilities and grounds and water for agricultural use.

Grounds that already have a concession but where the actual extraction has not yet started are not counted to this category. As minerals we include natural gas, petroleum, rocks and stones, gravel, clay, loam, marl, peat, sand (not the extraction in existing lakes and rivers) and salt.

**Company grounds** To this category are counted businesses and premises (including the storage yards, areas for transshipment and transfer of goods, parking lots, warehouses and company houses, working grounds and office buildings, infiltration grounds and the like) like factories, port areas, auction halls, exhibition grounds, cattle markets (both covered and outdoors), wholesale premises, storage yards for trade (also groundmoving businesses) and garages (including parking garages). Grounds for extension of businesses that have already been bought, rented or in ground lease are also counted to this category, as far as they border on existing grounds and as far as they are already changed from the original land use.

Not to this category belong fallow and wasteland, not yet finished sites for building, grounds that have been taken an option on but not yet been given out, harbour basins, clay excavation grounds for brick factories and company grounds no longer in use.

**Provision of services** To this category belong business areas in the service industry like shopping centres (also in case there is residential use on the upper floors), banks, insurance companies, ministries, town halls, offices for public works etc., border facilities (customs etc.), provincial government buildings, police stations, fire stations, courts of justice, prisons, goods markets (if they are used at least two days a week for this purpose), businesses in hotel and catering industry, garages of bus companies, laboratories.

Not to this category belong laboratories that belong the group of socio-cultural facilities (education, hospitals, judicial laboratories, other public facilities (waterworks, water treatment companies) and industrial facilities.

**Other public facilities** In this category are included public businesses (gas, water, electricity, district heating and central aerial systems including the grounds that belong to them, water treatment plants and incineration plants, including sludge fields, infiltration grounds (except those belonging to industry) and storage yards for the national, provincial and municipal governments (including municipal yards) excluding storage yards for road maintenance, storage grounds for slurry (dredge and port slurry), military objects like ammunition depot, barracks, mobilization centres, radar stations and rifle ranges (excluding barrack squares, that are counted as natural areas).



landscapes or urban parks. The drawings function as 'colouring pictures' that have not yet been filled in.<sup>318</sup>

### 6.3.6 Regional distribution<sub>100 and 30km</sub>

#### Drawing the existing situation

To draw the existing situation in different plan layers, one layer, the number of inhabitants per municipality, can be shown according to actual CBS statistics in real measure circles of 100,000, 10,000 and 1000 inhabitants (see Fig. 900).

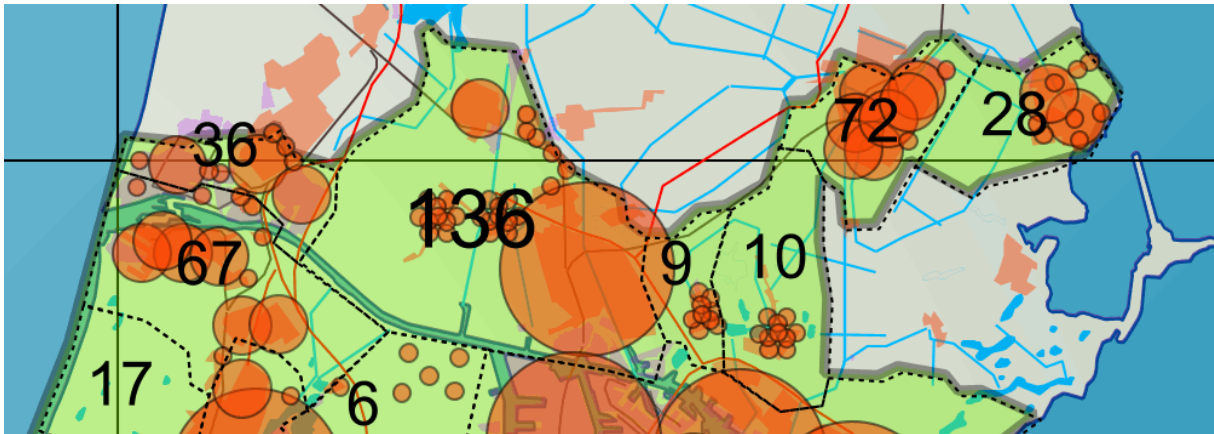
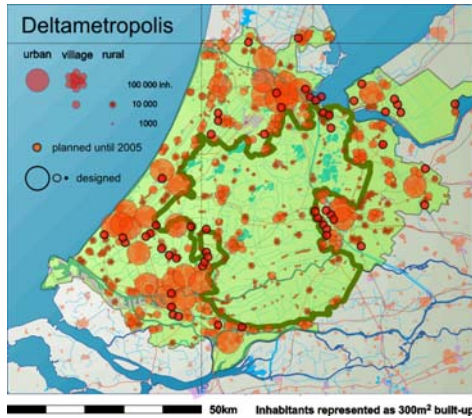


Fig. 900 Population statistics per municipality, drawn as circles of 3, 1 and 0.3 km radius of 100 000, 10 000, and 1000 inhabitants (300m<sup>2</sup>/inhabitant). These circles represent the built-up area such a population needs at average in The Netherlands. Their location is roughly determined by the urban topography read from the map.

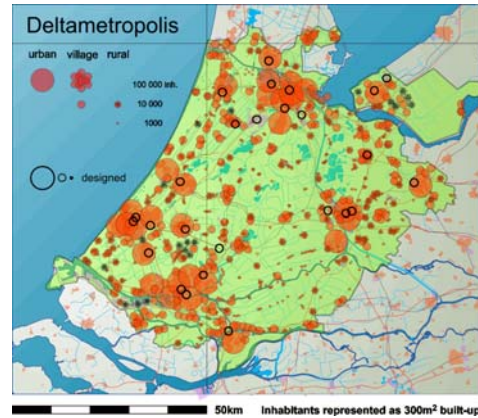
In such a pointillistic representation, a higher density than the current average in the Netherlands can be read off directly from overlapping circles. Dispersion within a municipality is quite accurately determined by the position of the built-up area on the map (see Fig. 900).

#### Adding existing local plans

To that has been added the capacity of existing municipal residential building plans, which, according to the New Map of the Netherlands 2000, is roughly estimated as being 570 000 inhabitants (see Fig. 901). This capacity has been aggregated with that of the existing built-up area to create a basic map for the year 2005, thereby making it possible to compare the designs. In this way, ten 1km units of 10 000 inhabitants (for example Amstelveen and Nieuwegein) could be aggregated into one 3km unit of 100 000 inhabitants. In a simple way, this represents locally increasing urbanisation, as distinct from expansion in general.



Nieuwe Kaart  
57x10 000



NRO5  
26x10 000  
187x1 000

Fig. 901 The year 2005: including existing plans

Fig. 902 The year 2030: NRO5

### Adding existing national plan NRO5

In Fig. 902 the remaining capacity of 5<sup>th</sup> National Plan of Spatial Policy NRO5 (intermediary scenario for 2030) has been drawn onto this background as a reference. That figure shows the mapped images of the existing situation, the plans that, according to the New Map of the Netherlands, are being carried out, and the part that remains after being subtracted from that for NRO5, according to the EC intermediary scenario (ABF).

### Interpreting plans

Fig. 903 shows the interpretation of NRO5 used in Fig. 902. In the same way other plans can be added.



Fig. 903 Interpretation NRO5

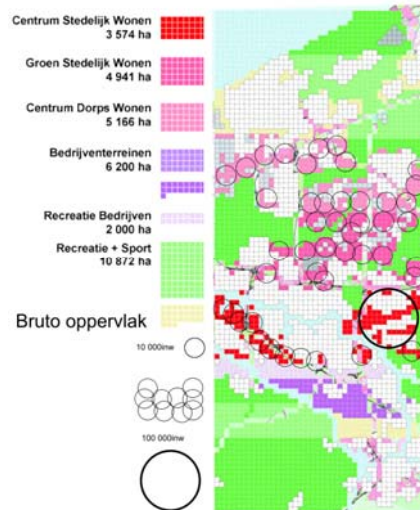


Fig. 904 Interpretation OMA

In OMA, 7, 12 and 13 squares of 25 ha are converted into circles of 10,000 inhabitants (Fig. 904). Ten circles in the centre of Rotterdam, within a radius of about 3 km are aggregated to a circle with a radius of 3 km (100,000 inhabitants).



### Adding complementary plans

OMA's and TKA's designs (see Fig. 904 and Fig. 905 respectively) are calculated back to the numbers of inhabitants from the design sketches, and, after subtracting the existing local plans, are distributed according to the topography of the drawings.



Fig. 905 Interpretation TKA



Fig. 906 Interpretation Snozzi

### Summarising and comparing with an alternative

Snozzi's design is interpreted exclusively and globally from the drawing (Fig. 908). In H+N+S's design, ABF estimated the capacity of the Green Heart to be 51 000 homes. This means about 100 000 inhabitants, represented as one dotted circle of 100 000 inhabitants in the middle of the summarising drawing of Fig. 907, because although a dispersion of 100 inhabitants (shown by small dots) might be possible, it is no longer visible or discernible. OMA, TKA and H+N+S's designs could now be represented in one drawing (see Fig. 907).

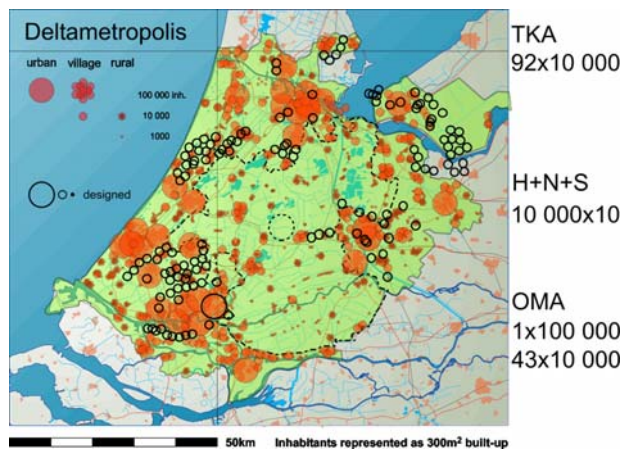


Fig. 907 Three complementary designs 2050

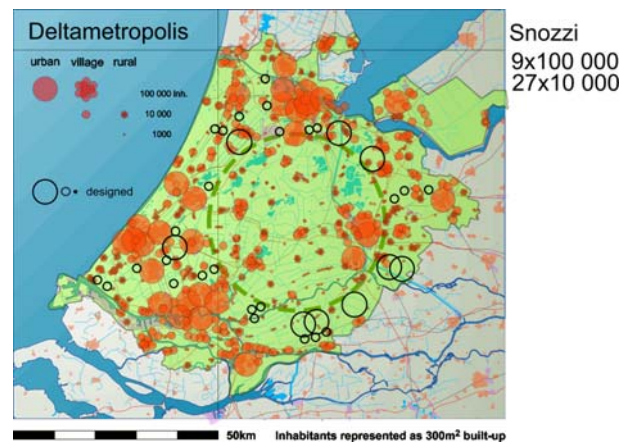


Fig. 908 Alternative Snozzi

Snozzi's design includes the entire Delta metropolis and is therefore drawn separately (see Fig. 908). The legends are restricted to units of 100,000 (3 km radius) and 10,000 inhabitants (1 km). In the background, units of 10,000 inhabitants have been divided into units of 1000 inhabitants (300 m), where the topography requires it. This has not been done in the design layer, which improves overall comparability.

### A comparison of quantities and rough morphology

Fig. 909 compares NRO5 with five alternatives: developing the South flank only, the Green Heart only, the North flank only, developing these three together, or following Snozzi's design.

Context	Population x 1000			OMA, South flank			H+N+S Green Heart			TKA, North flank			Total			Snozzi							
	Now present	Existing plans	NRO5-EC trend	100 000	10 000	1000	Inhabitants + existing plans	100 000	10 000	1000	Inhabitants, including existing plans	100 000	10 000	1000	Inhabitants + existing plans	100 000	10 000	1000	Inhabitants + existing plans				
recognisable on the map as:																							
Name:	2000	2005	2030																				
Urban centre	710	700	988	1			800			700	8			780	1	8			880			700	
Urban areas outside the centre	2818	2810	2448		11		2920			2810	25			3060		36			3170		9		3710
Urban green areas	415	410	655		16		570			410	35			760		51			920			3	440
Village centre	1337	1890	2090		16		2050			1890				1890		16			2050			24	2130
Rural living	251	400	505				400	10		500	24			640		34			740				400
Working area	512	380	454				380			380				380					380				380
<b>Total</b>	<b>6043</b>	<b>6590</b>	<b>7140</b>	<b>1</b>	<b>43</b>		<b>7120</b>	<b>10</b>		<b>6690</b>	<b>92</b>		<b>7510</b>	<b>9</b>	<b>27</b>			<b>8140</b>	<b>9</b>	<b>27</b>		<b>7760</b>	

Fig. 909 Five alternatives for NRO5 and their population specified to their urban or rural context

It can be concluded from Fig. 909, that OMA already realises the NRO5 programme in the South wing, while TKA exceeds it already in the North wing. The three plans together exceed the NRO5 programme by 1 million inhabitants. Snozzi arrives at an extra capacity of over 600,000 inhabitants. These extra capacities are mainly achieved in urban areas outside the centre. Centres score lower than in the NRO5 design. To answer economic questions by this kind of representation further differentiation of the comparison into contexts of living and costs can be elaborated by calculation<sup>a</sup>.

### 6.3.7 Density or real measure dots distribution

#### Misleading density comparisons if the compared surfaces differ

Density measures are abstract ratios of objects per area. To compare different areas, in principle, their surface has to be exactly the same, otherwise very different values could appear (see Fig. 910).

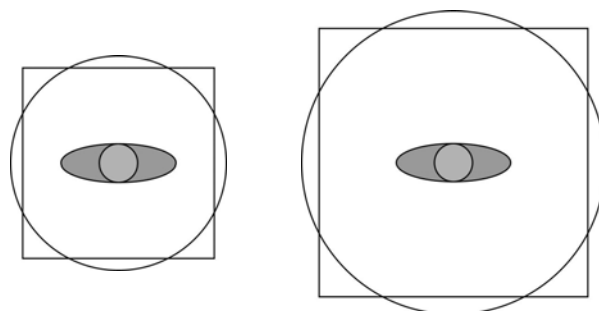


Fig. 910 The same person at 1 or 2 m<sup>2</sup> results in very different density values of 10000 or 5000 inhabitants per ha

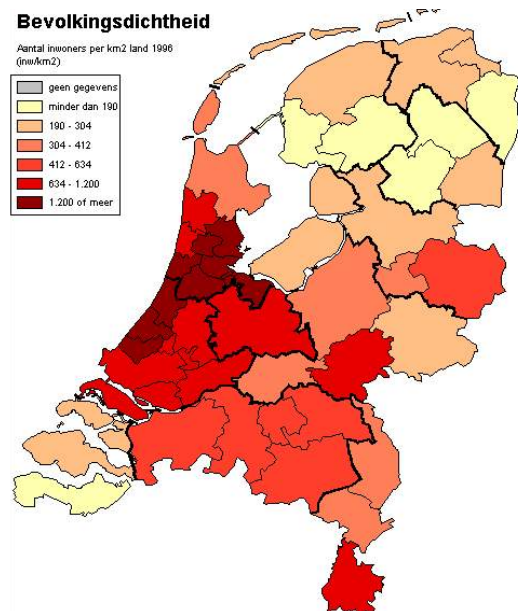


Fig. 911 Misleading image of densities applied on the different surfaces of COROP areas

<sup>a</sup> Jong ()

For example, the statistical COROP areas, based on temporary socio-economic and administrative boundaries, differ too much in surface to allow any comparison of variables like density with surface as a factor (see Fig. 911, where Rotterdam has a lower density than some smaller suburban areas).

### A misleading regular GIS-grids

Even a regular, exactly equal square km grid applied in GIS-applications can produce misleading images. An occasional boundary could divide a concentration or not, leading into very different images and conclusions, losing essential information and design qualities (see Fig. 912).

Data to compare contexts of living and their costs are lost in an average representation, while the easier to draw dot representation gives a more realistic image. Moreover, they can be counted per km<sup>2</sup> and by doing so, immediately translated in more abstract densities, while the reverse is impossible.

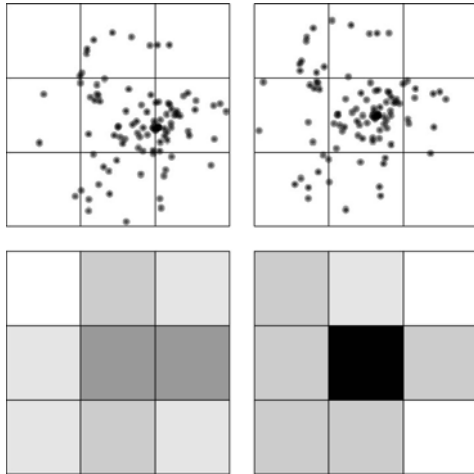


Fig. 912 Two average density interpretations of the same dispersion

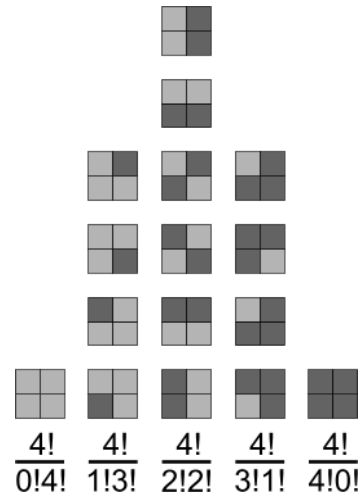


Fig. 913 Combinatorial possibilities of arrangement between emptiness and full coverage

From a viewpoint of design the grey values inbetween emptiness and full coverage give mathematically proven the most possibilities of arrangement (see Fig. 912, column in the middle) and probably the highest chance for high quality solutions. On page 518 we try to find other relations between density and quality, depending on the definition of quality.

### Mistakes using densities as a standard

While more advantages can be found in a representation of real measure dots distribution, density has the advantage to express an attribute of a site in one single number. That is why density is still very popular by administrators, developers and managers to formulate standards for design.

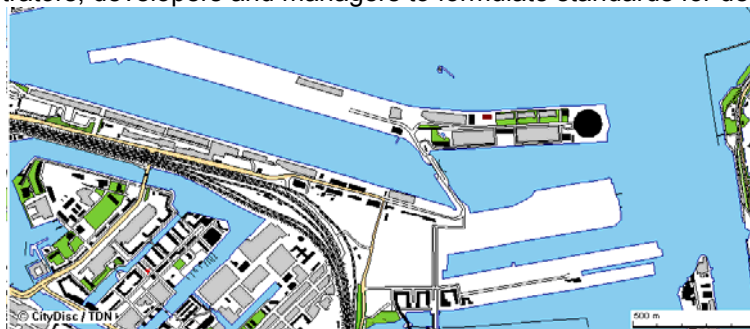


Fig. 914 The Amsterdam harbour islands, developed as residential area

However, densities are boundary-sensitive. So, if somewhere high densities are reached and used elsewhere, the comparison could be very disappointing. The residential plans for Amsterdam harbour islands (see Fig. 912) reached very high densities, often used as reference that such densities can be reached without loss of quality. However, when taking the surrounding water into account by



measuring the reached densities, their value would become much lower considering the effect of Fig. 910.

### Comparing designs by real measure dots distribution

Such mistakes can not be made representing plans by real measure dots distribution.

Normalisation into 4 visions of 50 000 new inhabitants within a square of 10x10km.



Zero variant

TKA 'residential'

Hoser 'recreation'

H+N+S 'nature'

Fig. 915 Comparing plans for Almere Pampus

Three plans for Almere Pampus, normalised into the same capacity were represented that way. This representation gives a rough, but direct idea of the visions. For many kinds of specialists like travel engineers, housing specialists, civil engineers this representation gives necessary starting points for evaluation. For every desired square kilometre you also can find the population density or floor-space index (FSI), because every dot represents 1000 inhabitants, now drawn by a circle of 30 000 m<sup>2</sup> floor space (100m radius net dots). If you like to count more or less than 30m<sup>2</sup> floor space per person, then the circles have to be drawn only a little larger or smaller.

### Extreme gross and net dots

In Fig. 900 the dots of 1000 inhabitants had a radius of 300m (about 30 ha or 300m<sup>2</sup> per inhabitant). These dots represent the average urban area an inhabitant needs for all urban facilities in The Netherlands according to the figures mentioned on page 502. However, in Fig. 915 they had a radius of 100m (about 3 ha or 30m<sup>2</sup> per inhabitant, the average floor space you approximately need for living only).

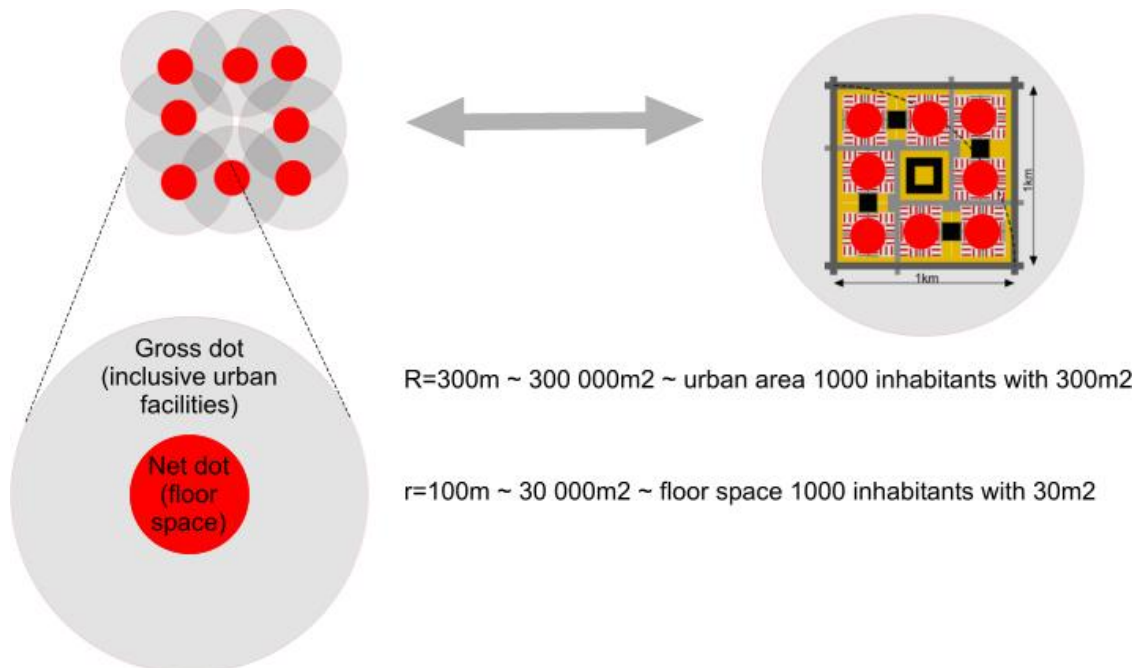


Fig. 916 Extreme gross and net dots

Within a district the gross dots of Fig. 900 would often overlap (see Fig. 916). Net dots already give some idea about the mutual arrangement of dwelling areas. In Fig. 915 the urban facilities other than homes have to be imagined in between the 'net dots'. In Fig. 916 the allotment of a district quarter is drawn showing the surface other than dwellings like surrounding facilities like green areas, pavement, schools and shops. However, the gross dots overlap, showing there is more than that, apparently outside the local district. So, measuring the density of a district with district facilities only (district tare) will be higher than the density of a town including town facilities (town tare). The same applies for any level of scale you take into account.

### Comparable surfaces in urban areas

By counting the digits of the number of m<sup>2</sup>, we could name these categories with a useful tolerance by their nominal radius (see Fig. 917). For example, you can name an area with a surface between 10000 and 99999 m<sup>2</sup> (5 digits): 'R=100m' (ensemble).

Digits	Min. area	Max. area	Min. radius	Max. radius	Nominal radius	Gross	Tare
	Smin	Smax	R <sub>min</sub>	R <sub>max</sub>	R <sub>nom</sub>	name of area	including for example
	m <sup>2</sup>	m <sup>2</sup>	m	m	m		subtracted on lower level
10	1000000000	9999999999	17841	56419	30000	metropolis	landscape parks, metropolitan infrastructure and facilities
9	100000000	999999999	5642	17841	10000	conurbation	town landscapes, conurbation infrastructure and facilities
8	10000000	99999999	1784	5642	3000	town, town quarter	town parks, town water, town infrastructure and facilities
7	1000000	9999999	564	1784	1000	district, district quarter, village	district parks, district water, district infrastructure and facilities
6	100000	999999	178	564	300	neighbourhood, hamlet	neighbourhood parks, small water, neighbourhood infrastructure and facilities
5	10000	99999	56	178	100	ensemble	small public green area residential public space
4	1000	9999	18	56	30	urban island, property, building complex	pavement directly opening up building complexes, open space in private parcels (lots, plots)
3	100	999	6	18	10	parcel, plot, lot or building	gardens, unbuilt places, patios
2	10	99	2	6	3	building segment,	rooms, unbuilt spots
1	1	9	1	2	1	building part	inaccessible spaces

Fig. 917 Ten different tare categories, ten different density measures

Though the range of surface difference is still a factor of nearly 10, this restriction is strict enough to get roughly comparable densities. However, even by that tolerance there are still ten different urban density measures to be confused. So, a gross density D<sub>100m</sub> is something else than a gross density D<sub>300m</sub>, but a net density D<sub>300m</sub> in this scale range is the same as a gross density D<sub>100m</sub>.

### 6.3.8 Metropolis density<sub>30km</sub>

Tokyo-Yokohama is the largest metropole, counting nearly double the number of inhabitants of the next five between 15 and 20 mln (see Fig. 918). New York covers the largest area. However, the way the areas are counted may differ making the comparability doubtful.



Nation	Urban Area	Population	Km2	Density
Japan	Tokyo-Yokohama	33200000	6993	4750
United States	New York	17800000	8683	2050
Brazil	Sao Paulo	17700000	1968	9000
South Korea	Seoul-Incheon	17500000	1049	16700
Mexico	Mexico City	17400000	2072	8400
Japan	Osaka-Kobe-Kyoto	16425000	2564	6400
Phillipines	Manila	14750000	1399	10550
India	Mumbai	14350000	484	29650
India	Delhi	14300000	1295	11050
Indonesia	Jakarta	14250000	1360	10500
Nigeria	Lagos	13400000	738	18150
India	Kolkota	12700000	531	23900
Egypt	Cairo	12200000	1295	9400
United States	Los Angeles	11789000	4320	2750
Netherlands	Amsterdam	1100000	324	3400
Netherlands	Rotterdam	1325000	531	2500

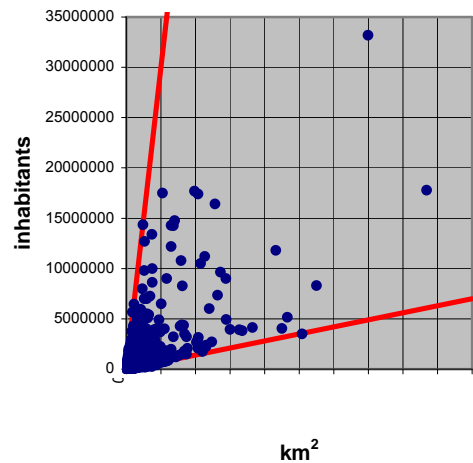


Fig. 918 The largest of 1200 cities listed by demographia.com

Fig. 919 1200 cities between the density lines 30 000 and 700 inhabitants per km<sup>2a</sup>

On the density lines of 30 000 and 700 inhabitants per km<sup>2</sup> (see Fig. 919) you find Mumbai and Atlanta as the largest cities, with incomes of €2 000 and €19 000 rper capita espectivevely. The €/capita income (see Fig. 920) and \$/capita gross domestic product (GDP, see Fig. 921) are very roughly related to metrolopan density.

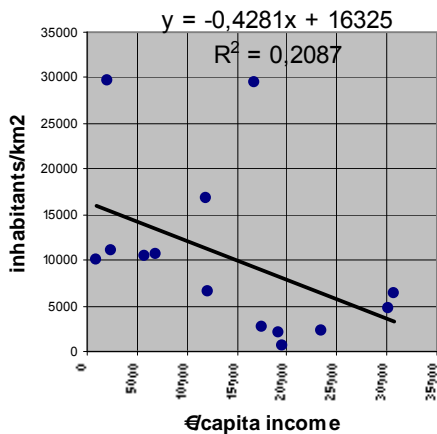


Fig. 920 Density related to €/capita income in 14 cases

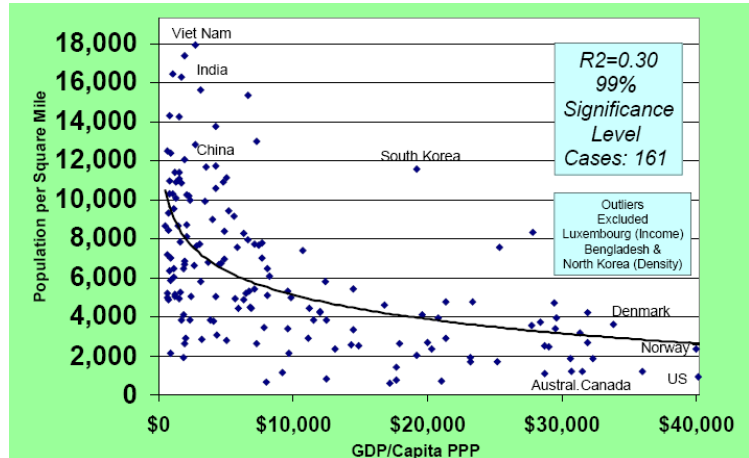


Fig. 921 Density related to \$/capita gross domestic product in 161 cases<sup>b</sup>

However the sources differ and the figures change rapidly. Van Susteren (2006) compared 101 metropolises on many aspects using different sources.

<sup>a</sup> <http://www.demographia.com/db-worldua.pdf>  
<sup>b</sup> <http://www.demographia.com/db-worldua.pdf>

### 6.3.9 Conurbation density<sub>10km</sub>

The municipality of Amsterdam has an average density of 4400, the municipality of The Hague 6500 inhabitants per km<sup>2</sup>. Are these figures comparable? No. The administrative municipality of Amsterdam comprises more vast empty areas than The Hague. Such empty areas have to be subtracted as tare surface. In *Fig. 922* and *Fig. 923* the built-up municipal area is dotted, but if you count the adjacent municipalities with more than 50% commuters into the central city, comprising at least 15% of their working population (see conurbation definition page 528), then the densities of these 'conurbations' are lower (2700 and 3300 inhabitants per km<sup>2</sup> respectively).



*Fig. 922 Population and floor space of Amsterdam* *Fig. 923 Population and floor space of The Hague*

Using population statistics per district and drawing dots representing 1000 inhabitants with a radius of 100m (30m<sup>2</sup> floor space per inhabitant), you can get an idea of the diversity of densities within these average conurbation densities (see *Fig. 922* and *Fig. 923*).

#### Deriving density from a distribution of dots

In *Fig. 923* a km grid is drawn. You can count the dots per grid cell to determine the local density per km<sup>2</sup>. However that depends on the location of the grid (see *Fig. 912*). It is better to make a mask of 1km<sup>2</sup> and shovel that mask over the drawing to find the highest density. Multiplying that figure by 100 gives the density of inhabitants per ha. Dividing it by the average household size gives an estimate of the number of houses per ha.

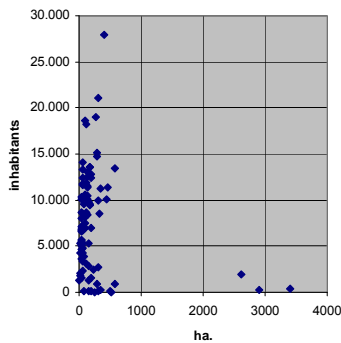
You can also estimate the floor-space ratio (FSI: floor-space index) multiplying the inhabitants by the used average (here 30m<sup>2</sup> at home, but you have to add other floor space, say 30+20=50m<sup>2</sup>) per inhabitant. A hundred times FSI gives %floor surface on a conurbation level. High densities may suggest high rise buildings (at a smaller-scale map, the dots could be drawn piled-up to suggest high-rise). However that conclusion is put into perspective on page 520. Inbetween home-dots you have to imagine the tare space for urban facilities. The largest of these are industrial areas, parks and natural areas like dunes.

### 6.3.10 Town density<sub>3km</sub>

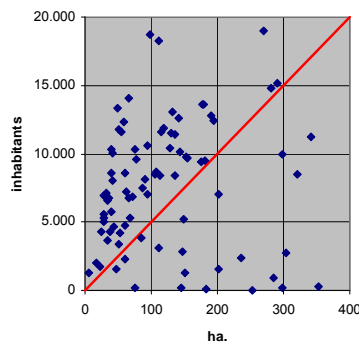
Town densities are incomparable if you do not precisely define the boundaries of the towns compared. To determine the main national subsidies for municipalities the distance between buildings has to be less than 100m to determine the 'built-up area' as a factor in subsidy calculation. That mainly means excluding 'open area' like agricultural areas, natural areas and parks larger than 100m in any direction as tare surface of higher order. The question if you have to include national or regional highways and waterways crossing the town and other facilities to calculate density has to be solved.

### 6.3.11 District density<sub>1km</sub>

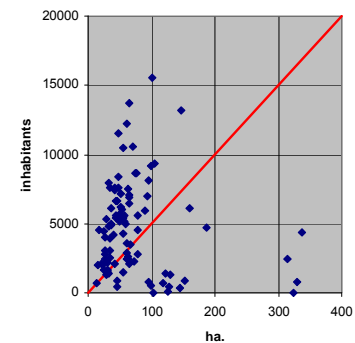
Many administratively bounded districts include such tare surfaces of higher order, not to be included to calculate district density. So, statistical figures about their total area are not reliable.



*Fig. 924 Inhabitants and surface of administrative districts in the municipality of Amsterdam*



*Fig. 925 The figures of Fig. 924 excluding districts of more than 1000 ha and 20 000 inhabitants*



*Fig. 926 The same figure as Fig. 925 concerning the municipality of The Hague*

*Fig. 924* shows the great difference in size of administrative districts in Amsterdam making these incomparable in principle. In *Fig. 925* districts of more than 20 000 inhabitants are excluded. They should be subdivided to be comparable with the smaller ones.

In the rough approach of *Fig. 917* you should exclude also districts with a surface counted in m<sup>2</sup> of more or less digits than 6, that is 2 counted in ha, but we can take an even rougher boundary.

Excluding three districts of more than 3 digits (>999 ha) in *Fig. 925* already gives an interesting view, but the question remains if you have to include urban highways and waterways crossing the district, town parks and other facilities derived from page **Error! Bookmark not defined.** (see also *Fig. 993*) to calculate density.

#### Rough boundaries of district density

In *Fig. 925* and *Fig. 926* the drawn line  $y=50 \cdot x$  ('inhabitants = 50 · ha') represents the density of 50 inhabitants per ha. So, the slope indicates the density. In both municipalities there is a concentration of districts with a higher density above this line. If you draw a line from 0(0) into 20 000(50), then you get the line of density representing 20 000/50=400 inhabitants per ha. Below that line none of the districts appear. However, on lower levels of scale with closer fitting boundaries you may find higher densities. You can also estimate the floor-space ratio (FSI: floor-space index) multiplying the inhabitants by the used average (for example 50m<sup>2</sup>) per inhabitant. A hundred times FSI gives %floor surface on a district level.

### 6.3.12 Neighbourhood density<sub>300m</sub>

#### Boundaries

Subdividing a municipality in partial municipalities, districts and neighbourhoods (see *Fig. 927*) raises questions of financial responsibility for (re)arrangement and maintenance of public space. So, determining the boundaries of that units becomes increasingly important on lower levels of scale. The smaller the area, the more the boundary surfaces count in relation to the enclosed surface. That is why such boundaries are often drawn on the middle of a shared road or waterway. If they are drawn on one side, the other side has to pay for it.

#### Subtracting tare of a higher order

In the beginning, private plots are sold, also paying for the surrounding public space as designed. However, if their neighbourhood comprises surfaces used by adjacent neighbourhoods as well, the costs have to be shared (tare of a higher order). That applies on every level of scale, from national scale until common roofs and walls in buildings and common hedges in gardens. So, in the initial exploitation scheme of a district or neighbourhood, these surfaces have to be distinguished as tare of a

higher order. A neighbourhood density calculation can use this financial distinction by subtracting such tare surfaces from the piece of map you take into account (the map cutting).

The result is a net neighbourhood surface, which is, according to Fig. 917, the same as the gross surface of all ensembles involved (see Fig. 929). Politicians are still interested in the reached number of houses per ha, but they do not often distinguish these surfaces. By using the 'net house neighbourhood density' (in fact the average 'ensemble house density') you can name a higher figure than using the 'gross house neighbourhood density'. However, as argued on page 503, floor space is more reliable than the number of houses to determine densities.



Fig. 927 Partial municipality Osdorp of Amsterdam, divided in 5 districts



Fig. 928 The 500x500m neighbourhood indicated in the middle of Fig. 927

- a m<sup>2</sup> Map cutting
- b m<sup>2</sup> Non district surface of higher order
- c m<sup>2</sup> Common district surface
- d m<sup>2</sup> Gross neighbourhood (a - b - c)
- e Number of houses
- f Gross house density per ha (10 000 · e / d)
- g m<sup>2</sup> Common neighbourhood infrastructure and facilities
- h m<sup>2</sup> Net neighbourhood (d - g)  
=m<sup>2</sup> gross ensemble surface
- i m<sup>2</sup> Total floor surface

Fig. 929 Primary figures to know on neighbourhood level

### Non residential surface

There could be many (political, social, financial, technical, ecological, spatial) reasons to distinguish residential and non residential surface. Non residential initiators may have to pay more for their plots per m<sup>2</sup>, they may need more parking space or other public facilities, they do not contribute to the number of inhabitants supporting shops and so on. That distinction may be not primarily important to determine the total %floor surface your design offers, but the distinction is often asked, especially if the non residential area is a substantial part of the total area. If you would like to take up that distinction in your density calculation, you need to specify more (see Fig. 930).

- |  |   |
|--|---|
| h m <sup>2</sup> Net neighbourhood (d - g)                   | p Average dwelling occupation (inh./dwelling.)                |
| i m <sup>2</sup> Total floor surface                         | q Inhabitants per hectare ((e x p)/(h/10000))                 |
| j m <sup>2</sup> Non-residential surface                     | r <b>Net residential surface (h - j)</b>                      |
| k m <sup>2</sup> Non-residential private surface (ca. 60% j) | s m <sup>2</sup> Housing floor surface (gf.+storeys.)         |
| l m <sup>2</sup> Total private surface (k + u)               | t Net house density (10000 e/r)                               |
| m m <sup>2</sup> Ensemble public surface (h-l)               | u m <sup>2</sup> Private residential surface                  |
| n m <sup>2</sup> Total built-up surface                      | v m <sup>2</sup> Public paved residential surface             |
| o %built-up, 100xGSR or GSI (100·n/h)                        | w m <sup>2</sup> Public green residential surface (r - u - v) |

Fig. 930 Secondary figures to know on neighbourhood level

Subtracting the non residential surface (j in Fig. 930), including the surrounding public space) from the net neighbourhood surface (h in Fig. 930, mentioned earlier in Fig. 929) produces a third surface you can take as a basis to name an even higher house density: the net residential neighbourhood surface (r in Fig. 930).

### Private and public space

Both total residential and non residential surfaces have to be distinguished in private and public space. If you do not want to measure the proportion of public space in a not yet designed non residential area (j in Fig. 930), you can take 60% as an approximation (k in Fig. 930), but you have to measure the private residential surface (u in Fig. 930) and the paved residential surface (v in Fig. 930) to check the third category, the green residential surface and water (w in Fig. 930).



### Inhabitants per hectare

If you know the average dwelling occupation (p in Fig. 930) and the number of houses (e in Fig. 930) you can calculate the number of inhabitants on the gross neighbourhood surface (h in Fig. 930). If you know the housing floor surface (s in Fig. 930) and the average floor surface per inhabitant (for example 30m<sup>2</sup>) you can divide them to get the number of inhabitants supporting the facilities of the neighbourhood.

### Built-up surface and building height roughly determine the floor space

The %built-up surface (100xGSI, Ground Surface Index) is an important part of private surface to determine the kind of environment your design produces (think about shadows). It is much work to measure that surface in a neighbourhood, but a free downloadable brain scanning computer application called ImageJ may help, if you have a topographical map in TIFF. format.<sup>a</sup> If you know the number of storeys you can roughly calculate the floor space by multiplying it by the built-up surface. However, some buildings cover open space losing floor space to be subtracted.

### Measuring and calculating

The Excel sheet below<sup>b</sup> gives these measures of neighbourhood density in their mutual relationship to make calculation easy. But you still have to measure many surfaces from the map or drawing.

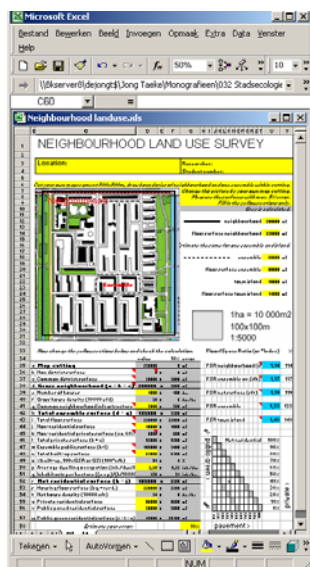


Fig. 931 An Excel sheet calculating of different kinds of density<sup>c</sup>

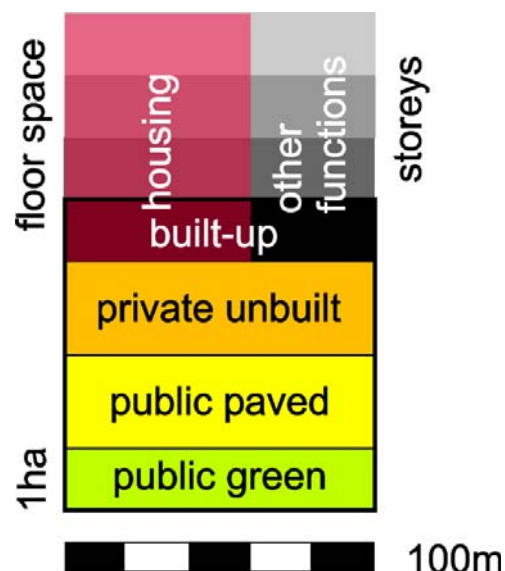


Fig. 932 Amsterdam Kinkerbuurt visualisation of surfaces per ha<sup>d</sup>

The urban development office of Amsterdam study group Kinkerbuurt from the sixties of previous century found an elegant way to visualise key factors of neighbourhood land use (Fig. 932).

### Five kinds of density

	for example	expressed as FSI
% floor space on gross neighbourhood (i/d)	114%	1.14
% floor space on net neighbourhood (i/h)	117%	1.17
% floor space on net residential surface (s/r)	119%	1.19
% floor space on a particular ensemble	133%	1.33
% floor space on a particular town island	140%	1.40

Fig. 933 The output of calculation: five kinds of density

<sup>a</sup> <http://team.bk.tudelft.nl/Databases/2004/GebruiksaanwijzingImageJ.doc>

<sup>b</sup> Downloadable from <http://team.bk.tudelft.nl> Publications 2003.

<sup>c</sup> <http://team.bk.tudelft.nl/> Publications 2003

<sup>d</sup> Hartman, W., H. Hellinga, et al., Eds. (1985)

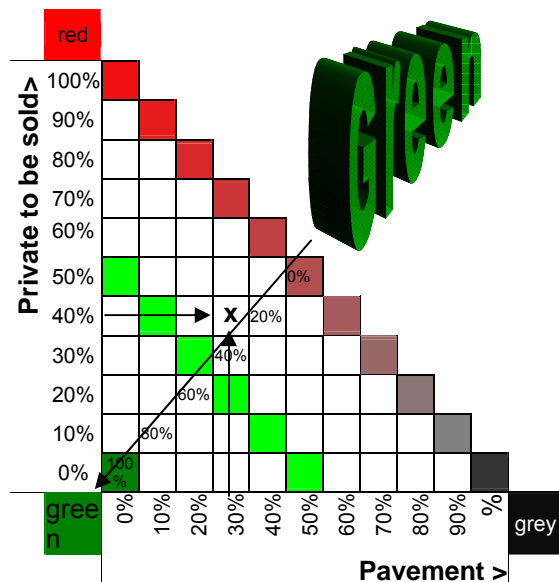
Fig. 933 shows the output of the Excel sheet: there are five kinds of increasing density you can distinguish, depend on what kind of surface you take into account. If you do not only take the floor space, but also the housing density, then there are another five.

**Private to be sold / public paved / green**

The private surface P raises the profits to be maximised, the public space A-P the costs to be minimised. However, a high amount of green, parking space and easy acces by paved circulation space may increase the ground price per m<sup>2</sup> of private lots. So, the proportion privat / public paved / green has to be optimised according to local context.

Politicians, project developers, housing corporations, professional colleagues or buyers often want to know the proportion of private plots to be sold, public paved and public green surface in the net residential area, determining qualitative and financial characteristics.

If three factors total 100%, you can visualise the proportion in a triangular graph earlier done in **Error! Reference source not found.** for three soil components. The Excel-sheet creates such a graph in a necessarily orthogonal way giving a cross in the appropriate cell (see Fig. 934) to be interpreted as a very rough rounded off indication.



In the Osdorp neighbourhood example of Fig. 928 the 46% net residential private ground to be sold and 27% pavement resulted in 26% public green are calculated in the Excel sheet of Fig. 931.

However, the graph with three 100% corners rounds these figures off into 40/30/30. The surface public green and pavement are rounded off at the cost of residential private ground to be sold. The graph is pessimistic about the profits.

So, this graph only can be used for a very rough comparison with other neighbourhoods, or has to be redrawn in a more precise triangular way like **Error! Reference source not found.** according to the real figures given as well.

Fig. 934 40% Residential private ground to be sold, 30% pavement and 30% public green

**6.3.13 Ensemble density<sub>100m</sub>**

**Simplified dimensions**

The division of a neighbourhood in ensembles mostly results in homogeneous residential or non residential areas. So, on this level that functional distinction will no longer play an important role. We can concentrate on basic formal surfaces as total area A, built-up surface B, floor surface F, private surface P, non-specified public surface A - P and average building height or average number of storeys S. The gross ensemble surface A is equal to the net neighbourhood surface (see h in Fig. 930). So, neighbourhood infrastructure and ~facilities are excluded, and there is only one basis for density: F/A (FSI). The coverage of the total surface A by buildings B/A (GSI) is a primary variable. B multiplied by the average number of storeys S (if façades are vertical) produces the floor surface F.



## Spacemate

If  $F = S \cdot B$ , then  $F/A = S \cdot B/A$ . To compare ensembles with different A, Permeta draws a diagram<sup>a</sup> called Spacemate, plotting  $F/A$  against  $B/A$ . In Fig. 935 both are given as percentage of B and F from the total area A. Moreover, the diagram is extended from 0 into 100%. So, B on the horizontal axis includes also unusual, mostly theoretical high densities.

In that diagram the %floor surface as a function of %built-up area appears as a straight line starting in the origin with a slope according to the average number of storeys. Any ensemble appears as a spot according to %F and %B (Fig. 935).

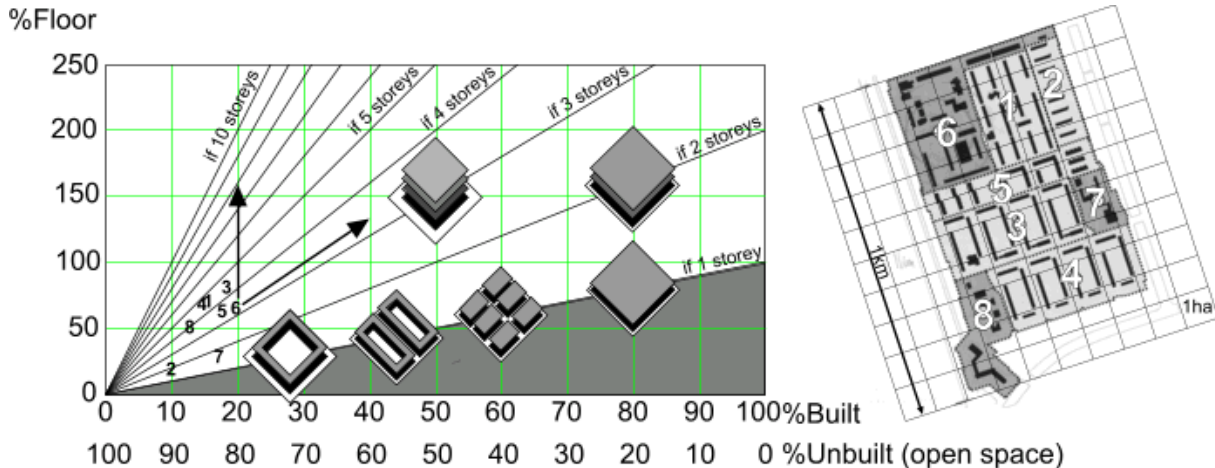


Fig. 935 Spacemate: floor surface as a function of built-up surface according to Permeta

In Fig. 935, 6 theoretical parcellations are drawn on 1 hectare (approximately 1 quarter of a nominal ensemble  $R=100m$ ). The 8 actual ensembles in Osdorp, Amsterdam West as measured by Permeta are given as numbers. They have all less than 20% built area, and the theoretical parcellations have more. For example, ensemble 6 has the highest %built surface, but not the highest %floor surface.

## Intensifying floor surface

Making plans to increase density in existing areas, political targets are often expressed in increasing FSI (%floor surface/100). The Spacemate is primarily made to visualise the qualitative effect of such operations. Permeta calculated many examples, real or made by students, on different spots in the diagram to show the effect. A computer programme shows different photographs of ensembles categorising them in clickable surfaces of the Spacemate.

To intensify the floor density you have to increase the building height or the average number of storeys (arrow crossing lines of floor density with the same number of storeys in Fig. 935) or without increasing the number of storeys you have to increase the %built surface (arrow parallel to lines of floor density with the same number of storeys in Fig. 935). By increasing the %built-up surface (decreasing open surface  $A - B$ ) more, one can cross the lines of floor density with average 3 storeys in horizontal direction even decreasing the number of storeys to 2 (draw it yourself).

## Urban quality

Most design alternatives will appear on 50% built-up area (see Fig. 913). Then the potential of urban-architectural quality and the length of façades, where building and open space are connected is highest (structural quality). However, lower levels increase the potential of open space, afforded views and green space (form quality), higher levels increase the support for schools, shops and other population-dependent facilities (functional quality). So, there are at least three components of urban quality directly related to the %built-up surface.

<sup>a</sup> PERMETA architecten (2002) Spacemate. FSI-GSI-OSR als instrument voor verdichting en verdunding (Amsterdam) Bureau Parkstad / TU-Delft, Faculteit Bouwkunde: 79, preceded by the graduation work of Meertens, R. (2000) Density? (Delft) DUT Faculty of Architecture.

Haupt Per and Meta Berghauser Pont (2005) *Spacemate@the spacial logic of urban density* (Delft) Imprint: DUP Science ISBN 90-407-2530-6

### More than 50% built-up area

Parcellations with more than 50% built area have seldom courts or streets larger than 10m width.



Fig. 936 Ensemble in Venice 1: 5000; 200x200m<sup>a</sup>

Fig. 937 Auction Aalsmeer 1:25000, ha grid of 1kmx1km, one building nearly covering a district

Such urban areas have no cars like Venice (Fig. 936) or they have internal traffic in buildings like the flower auction in Aalsmeer (Fig. 937).

### The use of open space

The elegantly simple and useful diagram by Permeta is complicated without necessity by introducing %unbuilt/%floor (OSR), or in formula:  $(A-B)/F$ . It is supposed that factor determines the use of open space: little unbuilt area compared to a large available floor space would give a pressure of floor-space users on the unbuilt area and for example a shortage of space for cars.

However, the intensity of use of public space (part of the open space) is not very dependent on use by local inhabitants. The traffic intensity of residential streets usually is 1% of its capacity (see Fig. 541). The expectation of urban liveliness (intensity) by design is overestimated in districts other than for example the city of New York. In student plans, that overestimate is frequently represented by drawing too much people in suburban public space. A global calculation<sup>b</sup> proves that you must be economical with the crowd pullers to get *some* lively places in the city. And to feed that, you need still a lot of quiet suburbs in the conurbation.

### Empty streets

That calculation goes approximately this way. According to the ground usage statistics of CBS<sup>c</sup>, in The Netherlands we have approximately 1 billion m<sup>2</sup> circulation area, whereas our population of about 16 millions (including home-bound children and elderly) is on the street at the most half an hour per person per day. This means that, on 100m<sup>2</sup> public area through the daytime, at average you will see someone driving or walking approximately one minute within a quarter of an hour. Assume that you call a public space as 'urban' in contrast with 'suburban' if you come across someone on 100m<sup>2</sup> for one minute long each minute ('urban intensity'). How much public space can be then 'urban'?

### Stealing liveliness from the suburbs

You must make almost 2000m<sup>2</sup> street elsewhere quieter for 100m<sup>2</sup> urban intensity, but not too quiet, otherwise people cannot come to the urban space you want to make 'urban'. That ends up then on 5% of the paved area. If you divide 3% of it concerning the districts, you keep still 2% for the concentration of urban crowd pullers. You should not subdivide urban crowd pullers too much; because you lure more people out of their house with bigger free choice-serving centres. You can at most try to make the public space so attractive, that people exchange the street to their television for a little bit longer than a half hour per day. Can a master plan contribute to that, or should you trust the architectural development?

<sup>a</sup> Novelli (1989)

<sup>b</sup> Jong, Taeke M. de (2004) Grenzen van Stedelijkheid (Zoetermeer) <http://team.bk.tudelft.Netherlands/> > Publications 2004

<sup>c</sup> CBS is the Dutch national bureau of statistics.

### Building height, number of storeys

Multiplying the Built-up surface by the number of Storeys produces the Floor surface  $B \times S = F$  (if all façades are vertical). So, the number of storeys  $S = F/B$ . If we make  $F = 100\%$  of the Area  $A$  ( $FSR=1$ ), then the Area is fully covered with one storey, half covered with two storeys, but doubling the number of storeys again reduces the profit of open space (see Fig. 938). So, piling up storeys is subject of diminishing returns in terms of open space, while the visual impact of the high rise on open space increases.

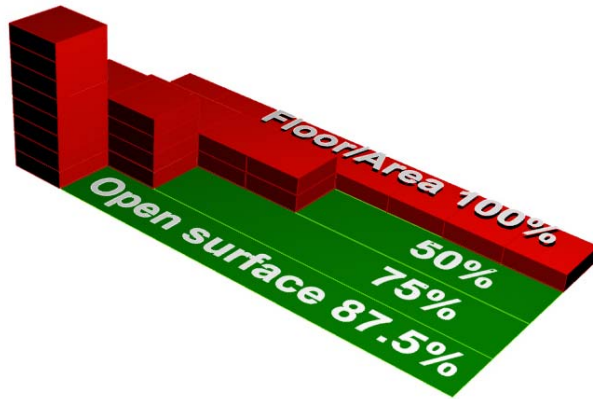


Fig. 938 Diminshing returns of open surface by increasing high rise building

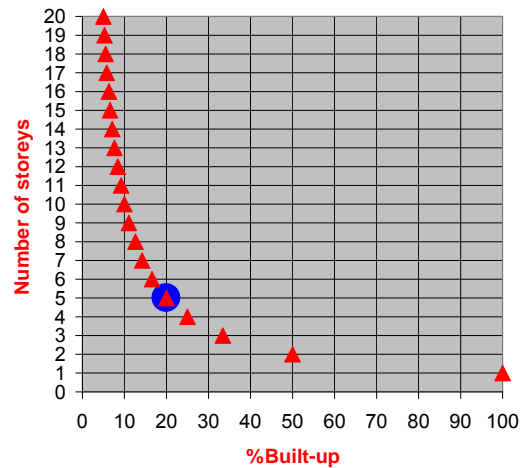


Fig. 939 Progressively increasing Built-up surface by decreasing number of storeys on 100%  $F/A^a$

The Built-up surface  $B$  is the complement of open surface. The %Built-up (of  $A$ ) is dependent on the number of Storeys  $S$  if we keep FSR or %Floor surface (of  $A$ ) constant. You can try different %Floor values yourself to change Fig. 939.<sup>b</sup> The profit of open space does not increase much above 5 storeys (blue spot in Fig. 939).

### Non-vertical façades

The Built-up area  $B$  is recognisable on the topographical map as the vertical projection of the building on the ground-level. However, for example a pyramid will have less floor space than a cube. So,  $F < S \times B$ . The same applies for buildings with different heights, extended parts, internal voids and non-vertical façades.

<sup>a</sup> <http://team.bk.tudelft.nl/> > Publications 2006 > %Built-up.xls

<sup>b</sup> <http://team.bk.tudelft.nl/> > Publications 2006 > %Built-up.xls

### 6.3.14 Urban island density<sub>30m</sub>

The urban island is the best level to avoid coincidental differences that could disturb a reliable density comparison. An urban island is bordered by the axis of public infrastructure that opens up or encloses private properties in closest surrounding not intersected by other infrastructure. So it encloses no other public infrastructure than dead-end streets, opening up backyards and garages, water and green area only functional to the smallest publicly opened-up urban area.

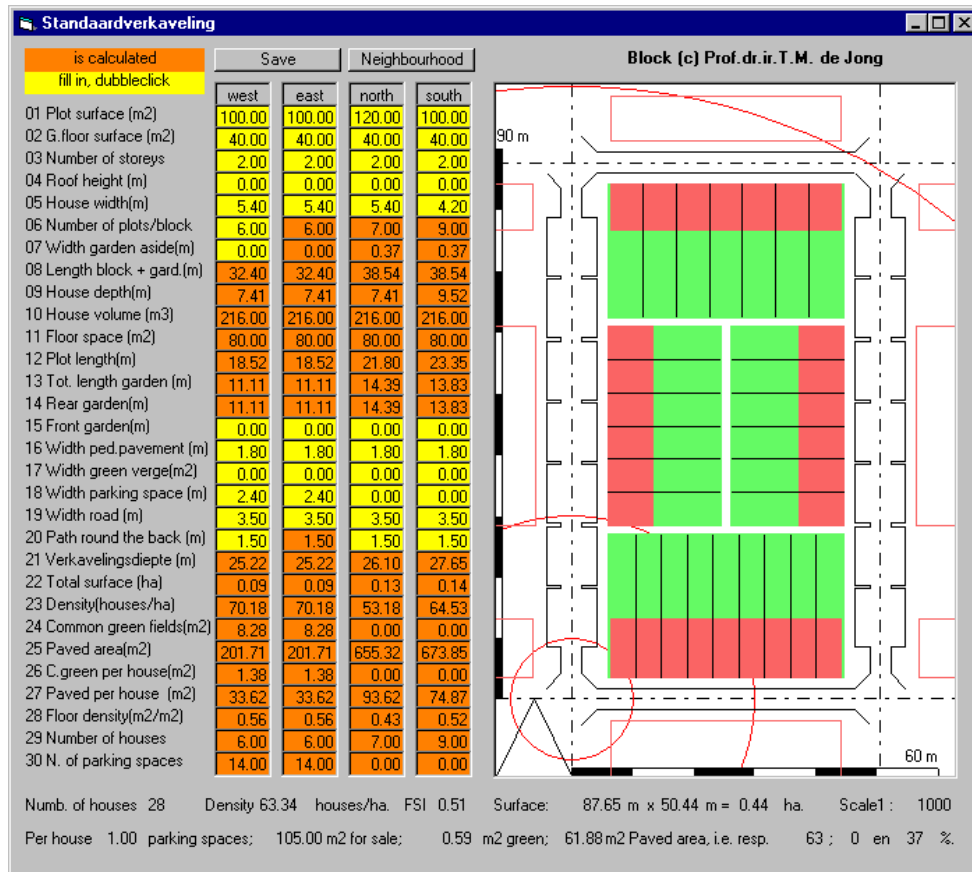


Fig. 940 The urban island<sup>a</sup>

An ensemble encloses several urban islands + ensemble infrastructure, a neighbourhood encloses several ensembles + neighbourhood infrastructure and so on. The %floor surface per area of an urban island is equal or higher than any other useful density measure by lack of urban tare, except the %floor surface of a particular plot (FAR). Jong (2001) made an interactive computerprogramme showing the behaviour of an orthogonal island changing any of the determining design measures (Fig. 940).

<sup>a</sup> <http://team.bk.tudelft.nl/publications> 2003

## Multiplying urban islands into a neighbourhood

Any higher level of scale adds its own tare decreasing the density. The programme shows in a next window the considerable surface occupied by dry and wet infrastructure on every higher level (Fig. 940).

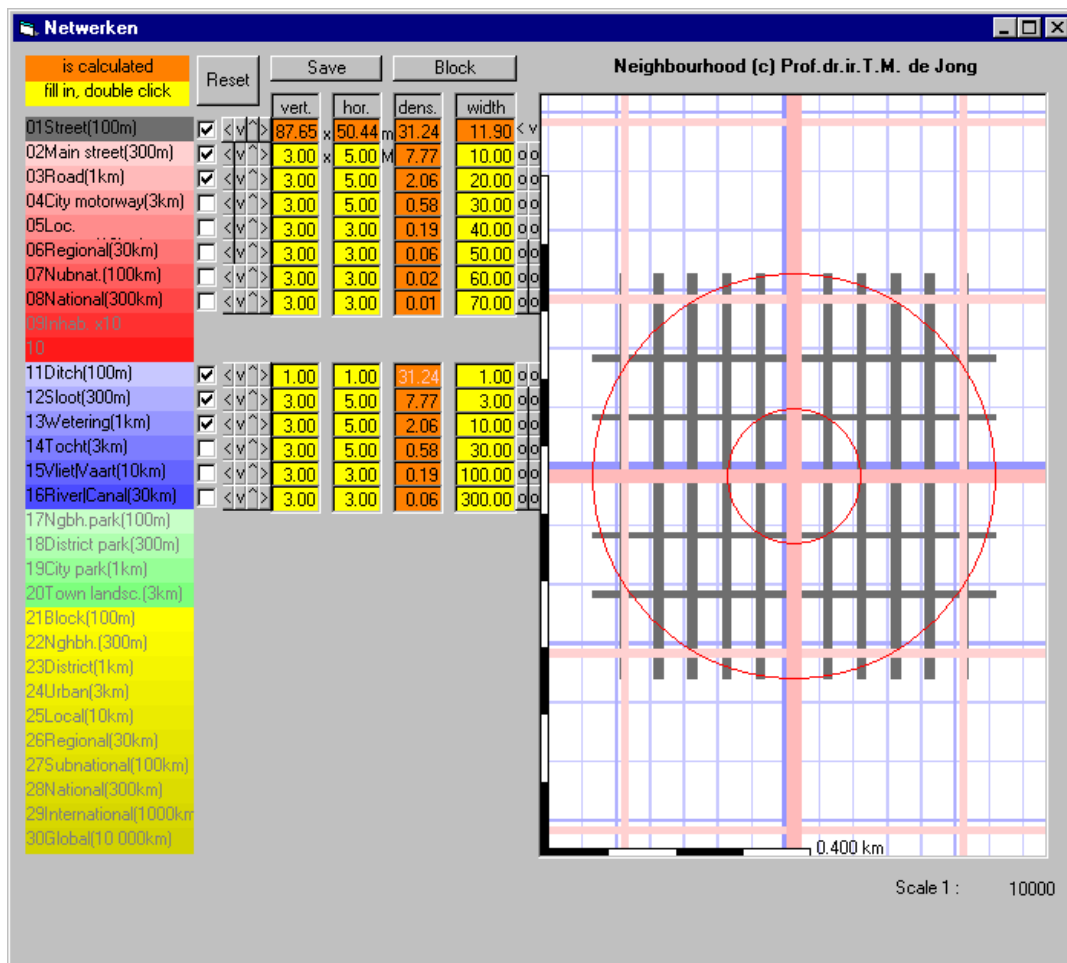


Fig. 941 Adding dry and wet infrastructure<sup>a</sup>

Green surfaces and surfaces for amenities are not yet shown in this window. It should be clear that such infrastructure of higher order should not be counted in the density of the lower order when they lack in other locations to compare. On this level of scale these surfaces are *location factors* by which the external *context* of the urban island differs, but not its *density*. They become comparable by density measures on a higher level of scale.

### 6.3.15 Urban details<sub>10m</sub> influencing density

Many questions<sup>b</sup> about the influence of urban details of a closed building block on density like built width and length, the building depth, the width and length of court, the width of streets, the width and length of island, the built-up surface, the %built-up, the average height of storeys, the number of storeys, the date and hour of sunlight<sup>c</sup>, solar angle limits, the outer wall ratio limit and the surface of outer wall are answered quickly by experimenting with all these measures in a downloadable spreadsheet (see Fig. 942)<sup>d</sup>. These parameters can be changed easily to find their influence on density. By experimenting with this spreadsheet you are warned for dark buildings, courts or streets changing them.

<sup>a</sup> <http://team.bk.tudelft.nl/> publications 2003

<sup>b</sup> Uytengaak (2005)

<sup>c</sup> see <http://www.jgiesen.de/sunshadow/>

<sup>d</sup> <http://team.bk.tudelft.nl/> > Publications 2006

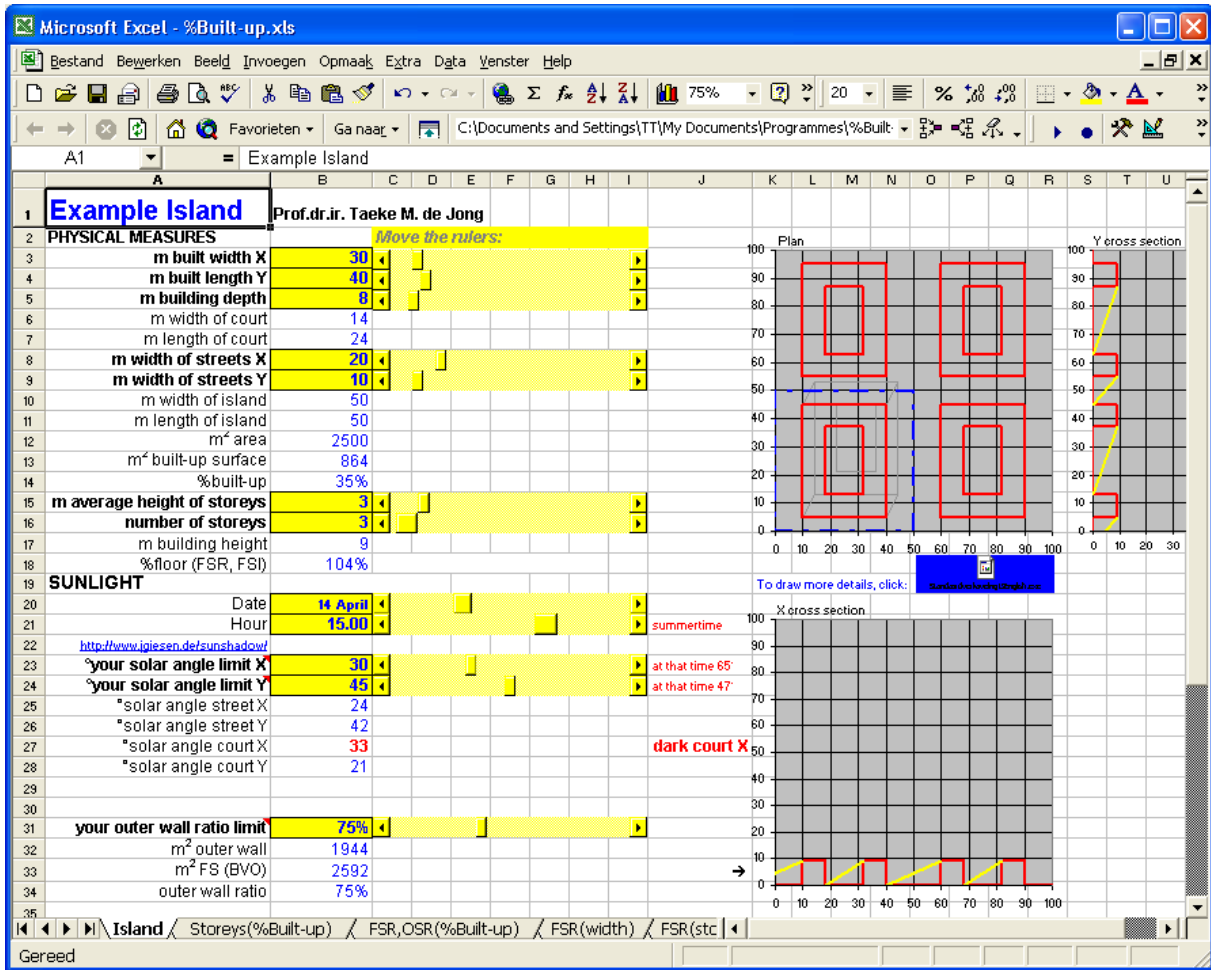


Fig. 942 The %built-up spreadsheet<sup>a</sup>

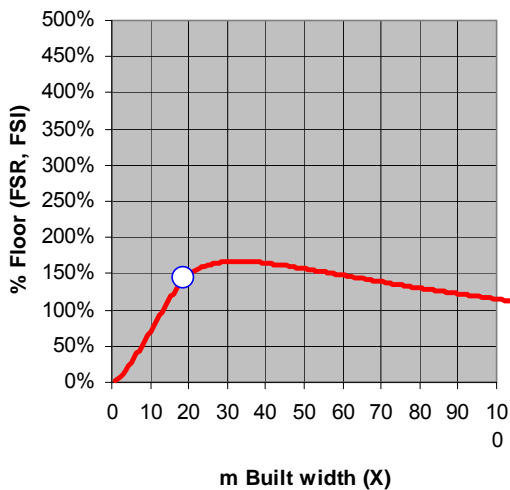


Fig. 943 FSR(Built with)

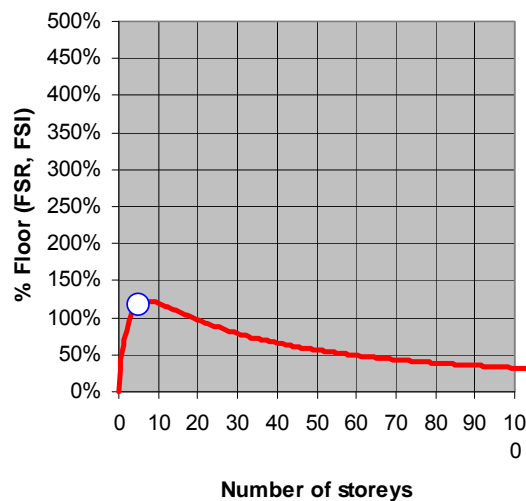


Fig. 944 FSR(Number of storeys)

Many graphs like Fig. 943 and Fig. 944 can be constructed according to their hidden suppositions about these parameters.

<sup>a</sup> living.xls, downloadable from <http://team.bk.tudelft.nl/> > Publications 2008



## 6.4 Economy

### 6.4.1 Dutch statistics

Every year, as far as I can remember, the the national bureau of statistics CBS has produced the Statistisch Jaarboek (earlier a more extensive Statistisch Zakboekje). Since 2006 it is also available in English (Statistical Year Book). This inexpensive publication gives an overview and a popular extract of CBS statistics (referring to much more data, to be found on <http://www.cbs.nl/>).

#### An example for direct use in urban design

There, for example, you can find characteristics of 240 urban facilities<sup>a</sup>. Dividing their number by total population of The Netherlands you can calculate how many people you need to support each facility at average. How many schools, restaurants, petrol stations has a Dutch district of 10 000 inhabitants at average? The deviation from this average determines the functional profile or identity of a region, conurbation, town, district or neighbourhood.

#### Intellectual substance

Those who are familiar with this pocket book are mostly of the opinion that one is not an intellectual unless one has a subscription to it. I support this view. At some point early in the year, as soon as my new copy falls through the letter-box, I settle down in a comfortable chair to look through it. Then, I am unavailable for a few hours, as, with the help of this impressive statistical material, I see numerous popular myths collapse before my eyes.



Fig. 945 The Dutch statistical year book 2008

#### Manipulating figures in Excel

It appears in the bookshops at the same time as the inexpensive CD-ROM. Like the website <http://www.cbs.nl/> this is a great blessing, because now all the tables can be transported to Excel and then the feast of selecting and working with this material can begin.

#### 1 Population

- 1.1 Population
- 1.2 Health and well-being
- 1.3 Education
- 1.4 Culture, recreation and other uses of time
- 1.5 Legal protection and safety
- 1.6 Residence

#### 2 Employment, incomes and social security

- 2.1 Employment and wages
- 2.2 Incomes, property and expenditures
- 2.3 Social security

#### 3 Businesses

- 3.1 Demography of businesses
- 3.2 Business book-year accounts
- 3.3 Automation and research and development (R&D)
- 3.4 Agriculture and fisheries
- 3.5 Energy and minerals
- 3.6 Industry
- 3.7 Building industry
- 3.8 National trade and service industry
- 3.9 International trade
- 3.10 Traffic, transport and communication

#### 4 Government, politics and management

- 4.1 Government finances
- 4.2 Politics and management

#### 5 Macro-economy and the money and capital market

- 5.1 National accounts
- 5.2 Money and capital market
- 5.3 Producer and consumer prices

#### 6 Geography and environment

- 6.1 Geography
- 6.2 Environment

Fig. 946 The content of the Statistisch Jaarboek 2001

A number of establishments are listed for every organization and branch. To give an impression of the kind of data you can find and manipulate, I have taken my CD-ROM *Statistisch Jaarboek 2001* with figures from 2000 and put the relevant urban architectural tables from the chapters indicated in Fig. 946 in Excel<sup>b</sup>.

<sup>a</sup> Summarised in living.xls, downloadable from <http://team.bk.tudelft.nl/> > Publications 2008

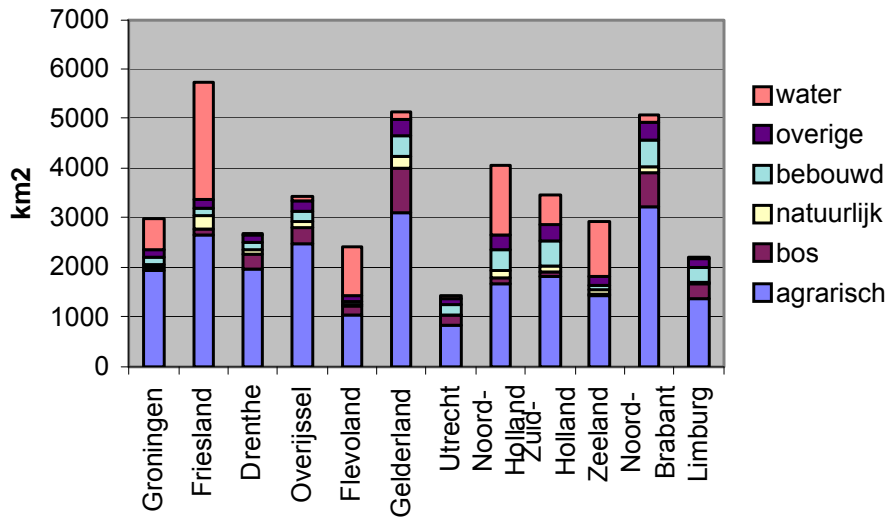
<sup>b</sup> <http://team.bk.tudelft.nl/> > databases

It is up to you to make the same graphs with more recent figures and to compare them with those of 2000.

## 6.4.2 Public space

### National territory

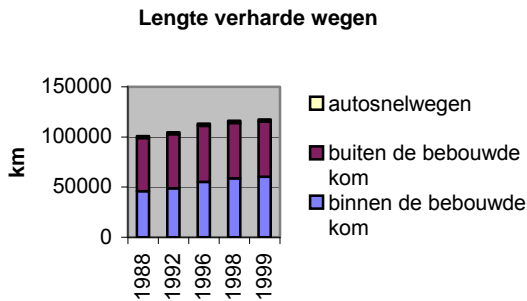
In 1996, the Netherlands occupied a territory of 41,526 km<sup>2</sup>, divided over various provinces and land-use categories, as shown in Fig. 947. Of these categories, forest, nature and water can be seen as public facilities, to a greater or lesser extent. Built-up areas occupy a relatively small area.



Legend: water, built-up, nature, forest, agriculture  
 Fig. 947 Land use in different provinces (from below: agriculture, forest, nature, built-up, otherwise, water) in the Netherlands

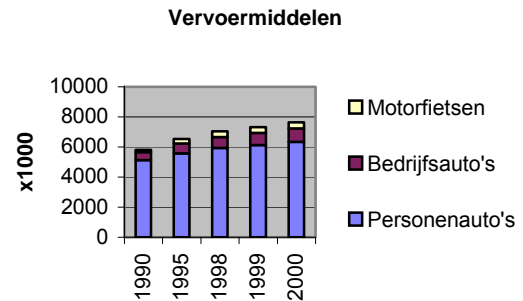
### The lengths of roads

In 1999, the Netherlands had 117,430 km of surfaced roads (if one was to include unsurfaced roads, this would be approximately 95% of the total road network). The growth of this road network is shown in Fig. 948. Although not all means of transport are public facilities, they form, together with the surfaced roads, a transport system (Fig. 949).



Legend: highways, roads outside and inside the urban area

Fig. 948 Extent of paved roads



Legend: motorcycles, business and private cars

Fig. 949 Means of transport

### The density of roads

Outside the built-up areas, the prevailing road network has an average mesh width of approx. 1 x 1 km (density 2 km per km<sup>2</sup>). Within built-up areas, the mesh width is almost 100 x 100 m (20 km per km<sup>2</sup>). Motorways have an average mesh width of approx. 30 x 30 km (0.07 km per km<sup>2</sup>).

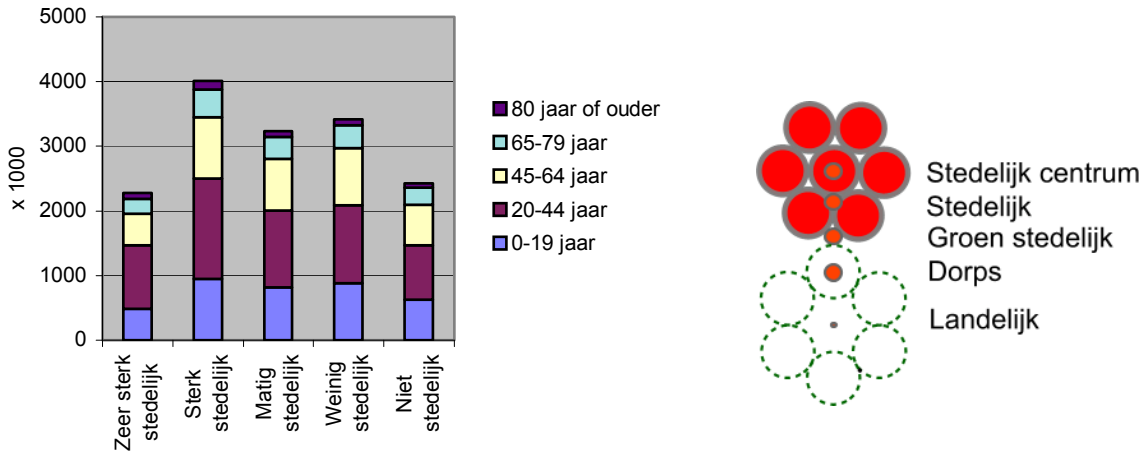
	length	surface area	density	average mesh width in km
motorways	2256	29261	0.077	30
outside the built-up areas	54820	26060	2.104	1
inside the built-up areas	60354	3201	18.85	0.1
total extent of surfaced roads	117430	29261	4.013	
railways	2808	33873	0.083	30

Fig. 950 The density of the road network

The density of the railway network can be compared with that of the motorways. Approximately 135 people are needed as a support base for a kilometre of road.

## 6.4.3 Urbanity

For the classification of urbanity the numerical values for the neighbourhood address densities of the different municipalities are categorised into five groups or classes.



Legend: urban centre, urban, suburban, village, countryside

Fig. 951 *Inhabitants by urban CBS environment category*

Fig. 952 *On the map*

The boundaries of the classes have been chosen in such a way that all the classes contain about the same number of residents. In this way, the following categories can be distinguished:

- very strongly urban municipalities with a neighbourhood address density of 2,500 addresses or more per km<sup>2</sup>;
- strongly urban municipalities with a neighbourhood address density of 1,500 to 2,500 addresses per km<sup>2</sup>;
- moderately urban municipalities with a neighbourhood address density of 1,000 to 1,500 addresses per km<sup>2</sup>;
- hardly urban municipalities with a neighbourhood address density of 500 to 1,000 addresses per km<sup>2</sup>;
- non-urban municipalities with a neighbourhood address density of less than 500 addresses per km<sup>2</sup>.

The number of residents who live in these environments is therefore divided rather similarly, with small variations in age.

In NRO5, the RPD used a similarly grouped classification to that of a stipple chart, for reading off a location.

### Order of municipality by size

On 1st January 2000, this population was resident in 537 municipalities. When one lists these municipalities according to size, one gets the 'ordering' of municipalities (rank size). In Fig. 953, using the ordering in this list, 1 in 40 of the municipalities is named. This does not produce a straight line, because the size of municipalities from the largest, downwards, diminishes rapidly, at first, before slowing down. When the y axis is made logarithmic, the graph becomes clearer (Fig. 954).

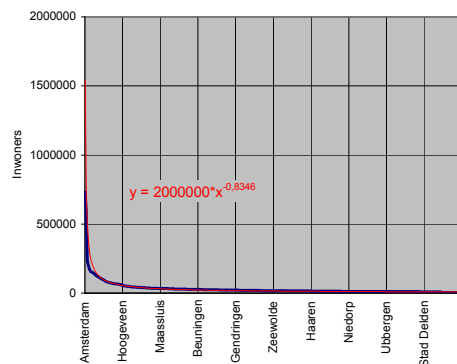


Fig. 953 *Ordering municipalities using a power trendline in Excel*

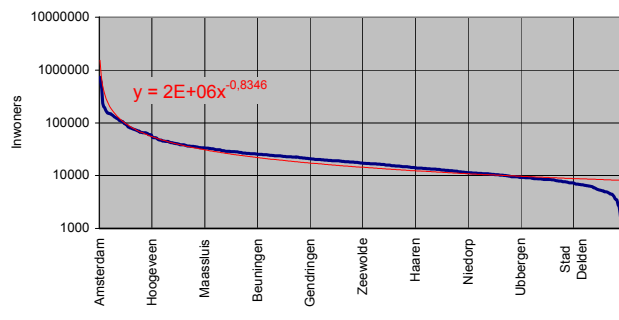


Fig. 954 *Ordering municipalities, expressed logarithmically, using a trendline in Excel*

Then it also becomes clear that, for the smallest municipalities, the trendline is no longer accurate: reality decreases faster for populations from below 10,000 to the smallest municipality (Schiermonnikoog), probably due to the geographical restrictions of the island boundary.

### Order of conurbations

The historical boundaries of municipalities cut through the reality of amalgamated built-up areas (urban conurbations), so that these graphs give an incorrect picture of the Ordering of urban areas. However, the *Yearbook* also gives a table of urban conurbations of over 100,000 inhabitants. The somewhat out-of-date definition of this type of conurbation is given in the *Yearbook* as follows:

A central town with surrounding municipalities that (on 31st May 1960) fulfilled the following conditions:

- more than 50% of the commuters resident there must be employed in the central town;
- in addition, the above-mentioned commuters must comprise at least 15% of the working population of the central town.

This table is shown next to the upper section of the municipality table (*Fig. 955*) in *Fig. 956*. In general, municipal density is much higher than conurbation density.

	inhabitants	km <sup>2</sup> land	no. inhabitants /ha.		inhabitants	km <sup>2</sup> land	no. inhabitants /ha.
Amsterdam	731288	165,13	44	Amsterdam	1E+06	365,12	27
Rotterdam	592673	208,61	28	Rotterdam	989956	355,50	28
DenHaag	441094	67,92	65	DenHaag	610245	187,50	33
Utrecht	233667	61,42	38	Utrecht	366186	140,93	26
Eindhoven	201728	87,31	23	Eindhoven	302274	181,27	17
Tilburg	193116	117,42	16	Leiden	250302	87,26	29
Groningen	173139	80,15	22	Dordrecht	241218	153,42	16
Breda	160615	127,00	13	Heerlen	218078	109,22	20
Apeldoorn	153261	340,30	5	Tilburg	215419	159,47	14
Nijmegen	152200	53,70	28	Groningen	191722	126,09	15
Enschede	149505	140,04	11	Haarlem	191079	76,67	25
Haarlem	148484	29,45	50	Breda	160615	127,00	13
Almere	142765	131,62	11	Amersfoort	154890	121,50	13
Arnhem	138154	98,57	14	DenBosch	154368	118,55	13
Zaanstad	135762	74,50	18	Apeldoorn	153261	340,30	5
DenBosch	129034	85,00	15	Nijmegen	152200	53,70	28
Amersfoort	126143	62,88	20	Enschede	149505	140,04	11
Maastricht	122070	57,01	21	Arnhem	139576	126,50	11
Dordrecht	119821	80,58	15	GeleenSittard	127322	98,13	13
Leiden	117191	22,16	53	Maastricht	122070	57,01	21
Haarlemmermeer	111155	180,01	6	Zwolle	105801	95,35	11
Zoetermeer	109941	35,59	31				
Emmen	105972	340,56	3				
Zwolle	105801	95,35	11				
Ede	101700	318,29	3				

Fig. 955 Municipalities > 100,000 inhabitants

Fig. 956 Conurbations > 100,000 inhabitants

From these tables, it appears that some conurbations (Heerlen and Geleen–Sittard) are composed of municipalities smaller than 100,000 inhabitants, while a number of municipalities (Almere, Zaanstad, Haarlemmermeer, Zoetermeer, Emmen and Ede) with more than 100,000 inhabitants are missing, partly because, due to commuting, they have been included in the conurbation of a larger municipality nearby. *Fig. 957* shows the Ordering of the agglomerates in *Fig. 956*.



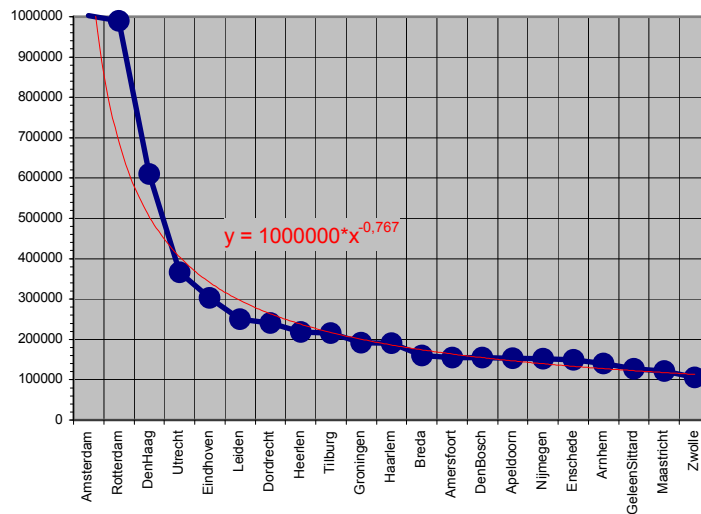


Fig. 957 Ordering of conurbations

### Going beyond The national order

In the Netherlands, two large conurbations dominate the ordering. If Amsterdam had 2 million inhabitants, the ordering would fit better into the formula. When we map the deviations from the formula (Fig. 958), then Amsterdam or Rotterdam, and, to a lesser extent, The Hague, are incongruous. This can indicate an international position, which has its own order. Following this line of thought, then, Utrecht falls within the national ordering.

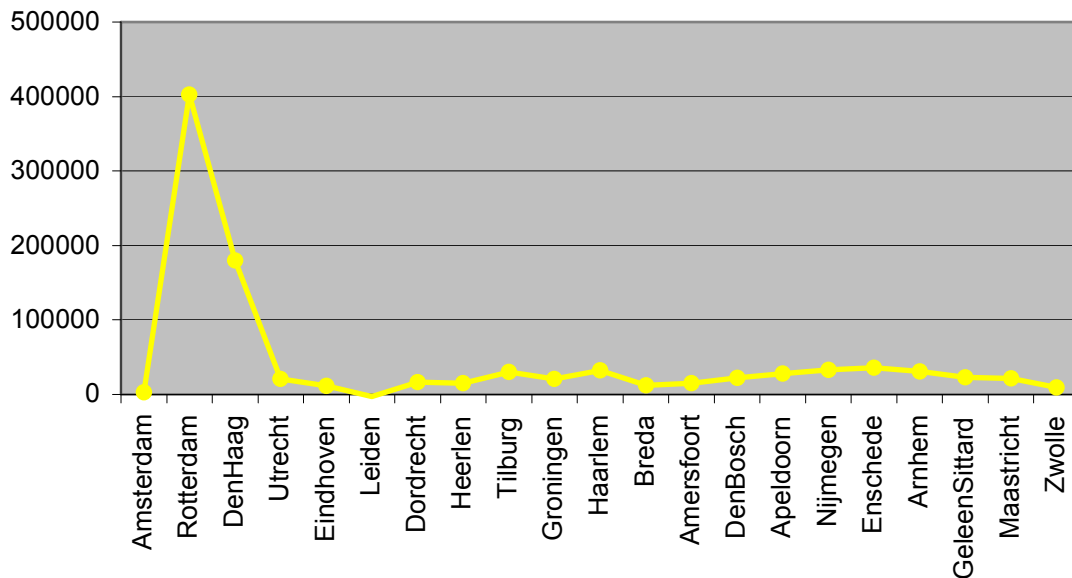
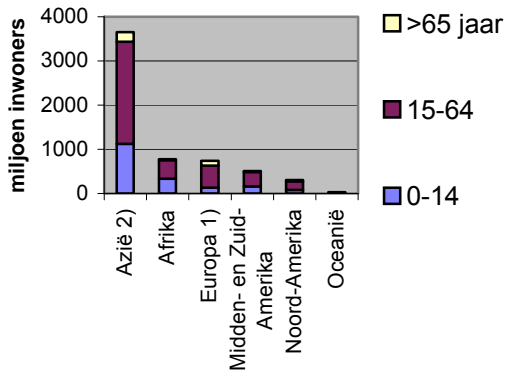


Fig. 958 Deviations from the ordering  $y = 1000000 \cdot x^{-0.767}$  in the higher regions

## 6.4.4 Population

### Compared to other continents

Compared with Asia, Europe is not only small, but, in contrast to all other continents, its population is much older (Fig. 959 en Fig. 960).



(1) Including Russia, excluding Turkey. (2) Including Turkey.

Fig. 959 Number of residents per continent

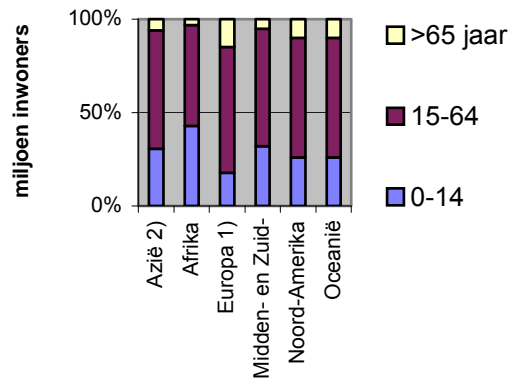


Fig. 960 Age range per continent<sup>a</sup>

### Population development in the Netherlands

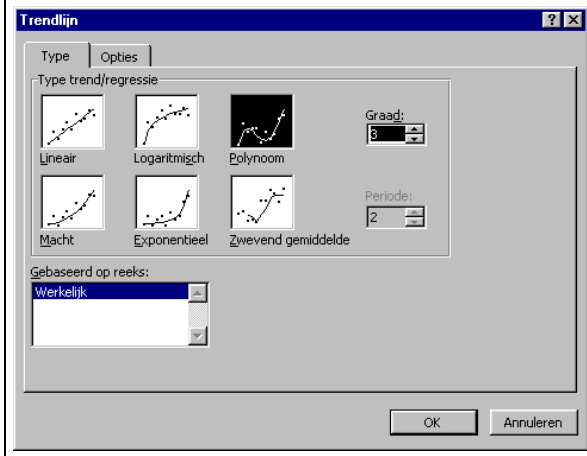
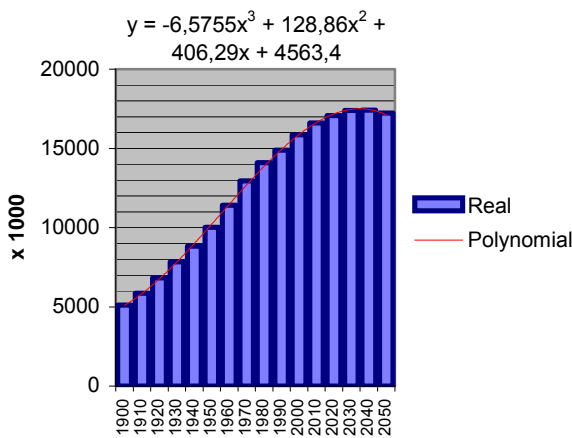


Fig. 961 How the Dutch population has developed (see also Fig. 840), using a polynomial trendline from Excel

When you make a chart in Excel to show how the Dutch population has developed (omitting the years between the 10s), you discover that, for a century, every 10 years, the population has increased roughly by a million. Select a chart and click on the toolbar 'chart/add trendline' and you will find the above menu (see also Fig. 425). If you choose a third-degree polynomial and, from 'options', click on 'show equation in chart', then you get the above result. A polynomial appears to fit in well here, and allows interpolation between the available years, but it has no rational linkage at all with reality. To find that kind of formulas is the task of demography (see page 464). So, it should not be used for extrapolation.

<sup>a</sup> U.S. Bureau of the Census International Database

### Population characteristics

After World War 2, the number of people per household (which almost equates with 'occupance per dwelling') decreased from 5 to 2.3 and the expectation is that it will decrease even further. From an urban point of view, this is an important figure because this halving of occupancy meant that, for the same population, twice as many dwellings had to be built (Fig. 962). Family dilution has mainly come about due to the increasing number of single-family households (Fig. 963).

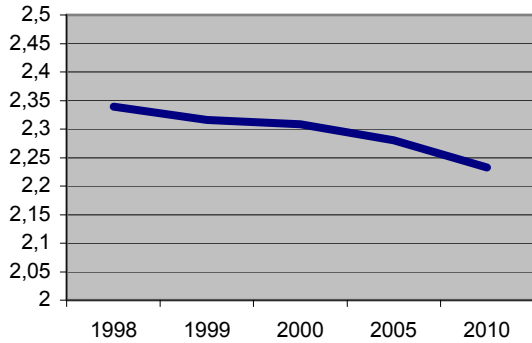


Fig. 962 Average number of people per household

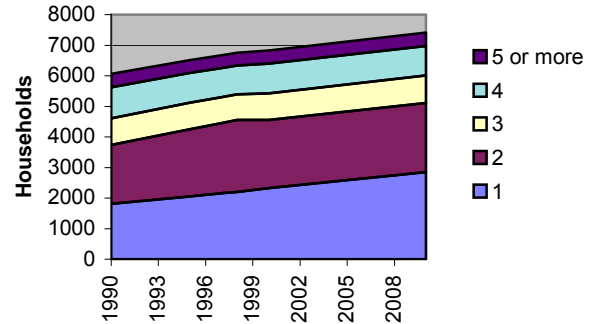


Fig. 963 Number of people per household

### Ageing

The population continues to age, but the question is whether, under the new politics, the number of immigrants will continue to grow as was forecast in 2001.

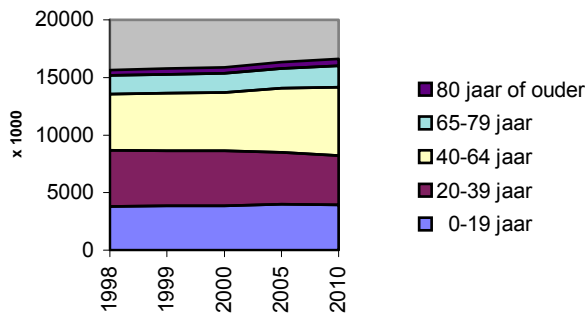


Fig. 964 Changes in age range

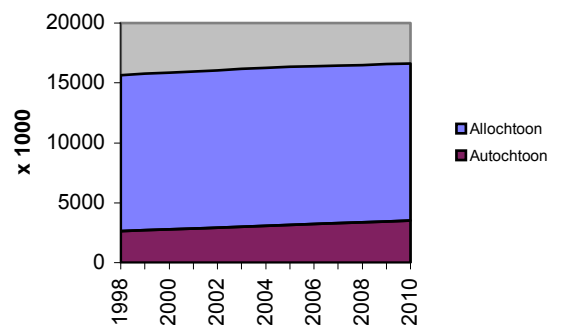


Fig. 965 Proportion of first and second generation immigrants

## 6.4.5 Time and movement

### Time utilisation

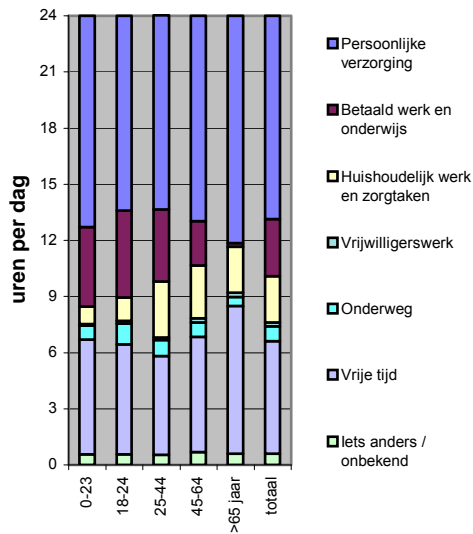


Fig. 966 Time utilisation in 1997

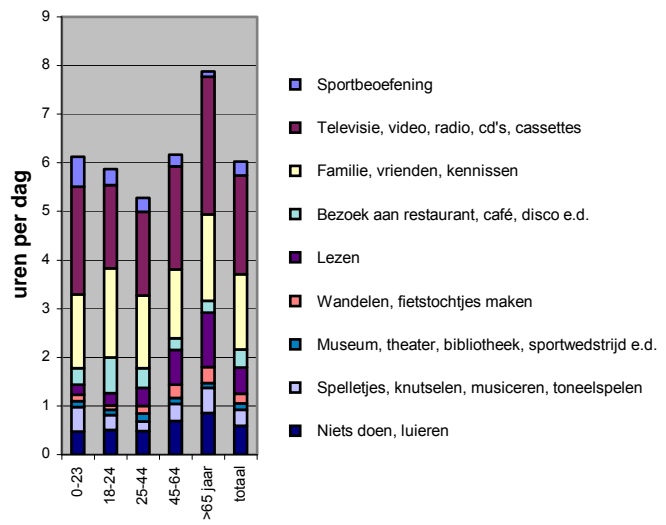


Fig. 967 Use of free time in 1997

### Daily population movements

The average total distances travelled, mainly by car, per person per day is fairly constant at 35 km (Fig. 968). Commuting accounts for almost 10 km of this distance (Fig. 969).

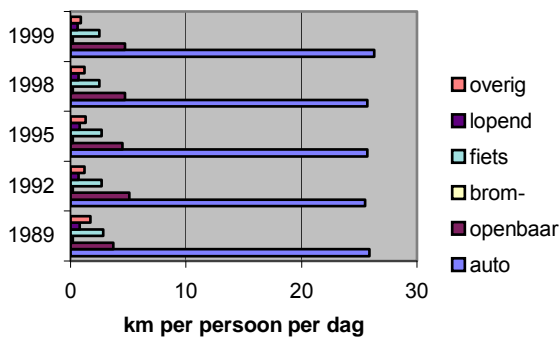


Fig. 968 Total distance travelled per means of transport

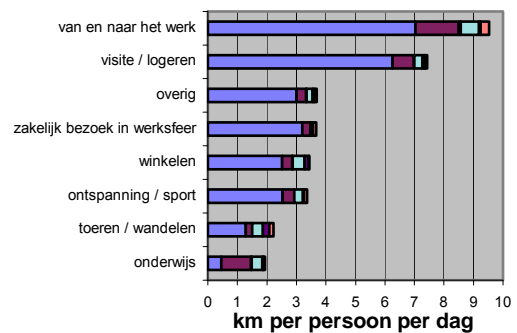


Fig. 969 Distance travelled per motive and means of transport

## Removals

In 1999, 1,696,000 Dutch people moved to another place of residence in the Netherlands. More than a million of these changes of address were within the same municipality (3 km radius), more than a quarter of a million within the same province (30 km radius) and almost 0.4 million from one province to another (300 km radius).

Removals in 1999  
within

3km 1058000 See Fig. 970  
30km 267000 See Fig. 971  
300km 371000 See Fig. 972  
total 1696000

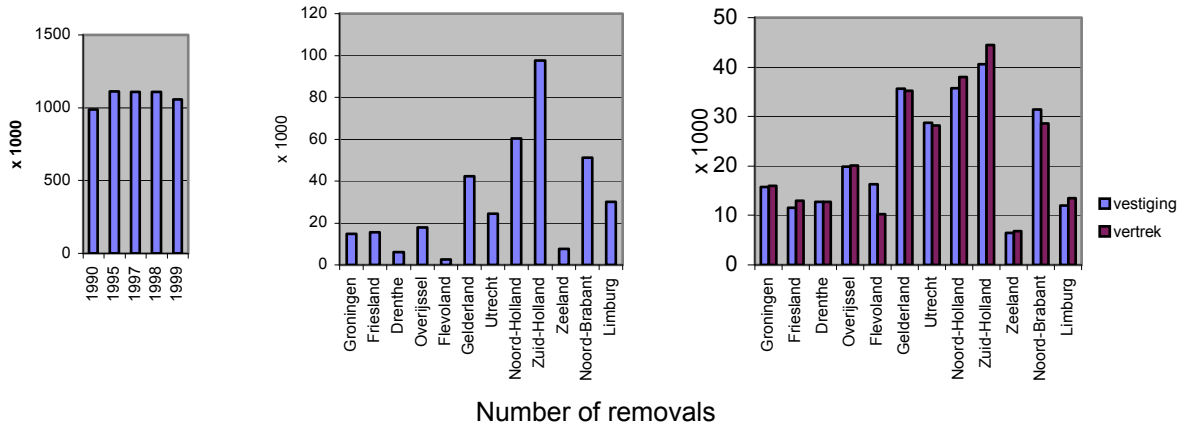


Fig. 970 Municipal

Fig. 971 Provincial

Fig. 972 National

The largest number of removals took place within and between the provinces South and North Holland.

## 6.4.6 Dwellings

### How many of each kind

On 1st January 2000, in the Netherlands, there were approximately 6,588,000 homes, the value of which totalled € 575,945,000,000, divided into categories, as shown in Fig. 973

	year	population x 1000	number of dwellings	support base in persons
<b>Home</b>	1999	15760	6390100	2.47
Own home	1999	15760	3303700	4.77
Rented home	1999	15760	3086400	5.11
Home with central heating	1999	15760	89700	176
Flat/apartment, etc.	1999	15760	1965000	8.02
End of terrace-/terraced house	1999	15760	2689900	5.86
Home with a garden or grounds	1999	15760	75600	208
Home with a garage and/or a carport	1999	15760	33600	469
A detached house	1999	15760	979400	16
A semi-detached house	1999	15760	755800	21
A 1 or 2-roomed home	1999	15760	580500	27
A 3-roomed home	1999	15760	1273800	12
A 4-roomed home	1999	15760	2164100	7.28
A 5-roomed home	1999	15760	1556300	10
A home with 6 or more rooms	1999	15760	815400	19

Fig. 973 Housing categories and their number in relation to the total population of the Netherlands



So, on every 19 inhabitants there was a dwelling with 6 or more rooms.

### Price and age

From Fig. 974 and Fig. 975 you can determine the average age and price of dwellings.

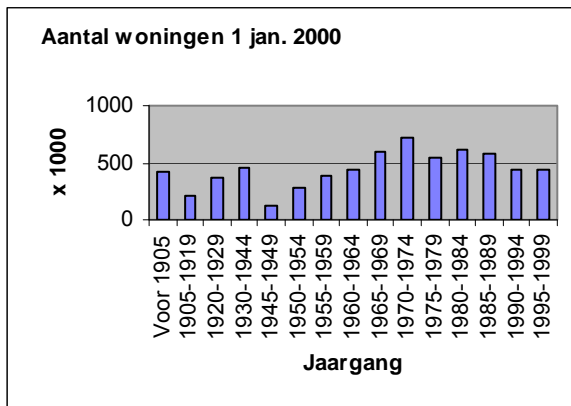


Fig. 974 Number of homes per year of construction

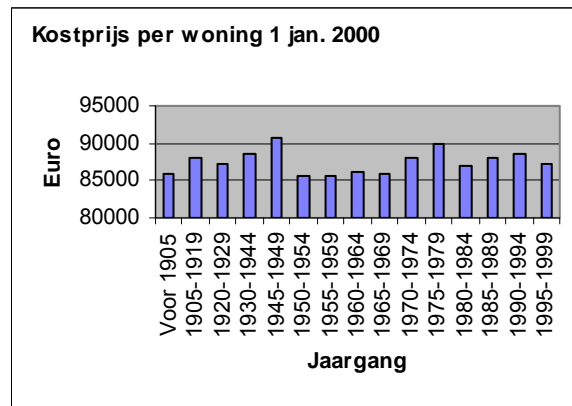


Fig. 975 Value of home per year of construction

### Singles rent, families buy mainly new houses

The majority of people in the Netherlands live in accommodation that was built after World War II, between 1960 and 1990 (Fig. 976). Single-person households are mainly accommodated in rented homes. Couples usually buy their own living accommodation (Fig. 977).

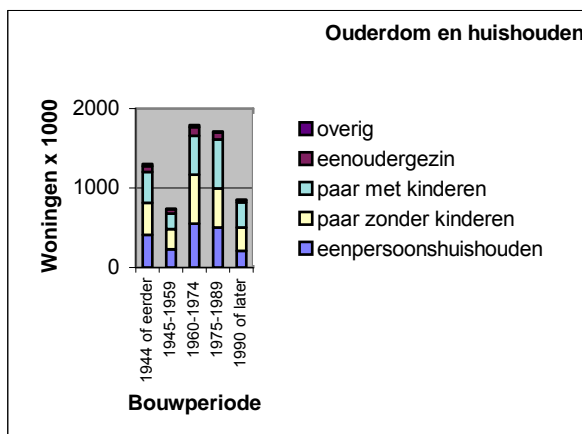


Fig. 976 Occupancy per year of construction

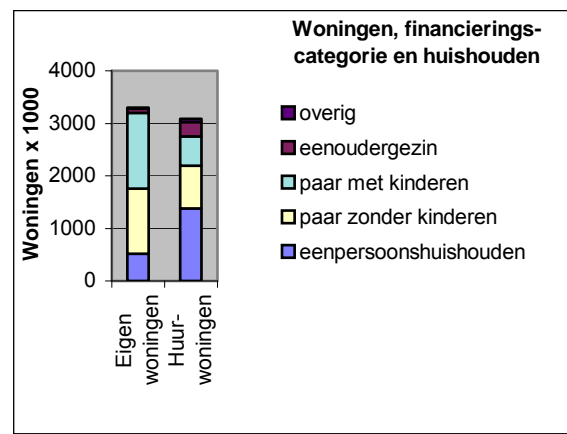


Fig. 977 Occupancy in own or rented houses

## 6.4.7 Public utilities

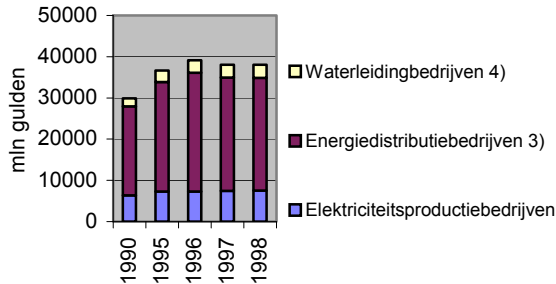
### Less energy companies and water boards

The number of water boards has decreased from 32 in 1990 to 20 in 1998. However, the number of employees or cubic metres of water produced remained the same (Fig. 980). As with agrarian firms, this indicates concentration.

Establishments for:	year	population	number	growth per year	support base
Electricity producing company	1998	15654	5	0%	3130838
Energy distribution company	1998	15654	70	-1%	223631
Water Board	1998	15654	20	-9%	782710

Fig. 978 Number of utility facilities compared with the size of the Dutch population

### Decreasing energy and water production



Note 3: Including power installations(>50 GWh per year), in the context of joint ventures, exploited by energy distribution companies and industrial companies.

Note 4: Excluding multi-utility companies.

Fig. 979 Production value of utility companies

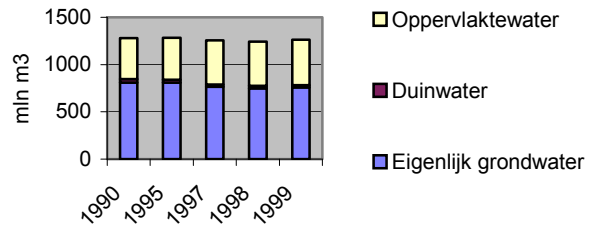


Fig. 980 Water production

### Selective increase of facilities for health and welfare

Establishments for:	year	population	number	growth per year	support base
after-school care centres	1998	15654	992	18%	15780
hostels caring for vagrants and homeless people	1999	15760	228	5%	69124
host-family care centres	1998	15654	189	1%	82826
half-day crèches/nurseries	1998	15654	169	9%	92628
full-day crèches/nurseries	1998	15654	1749	16%	8950
family doctors'/ general practitioners' (gps') practises	2000	15864	4809	0%	3299
established general practitioners (gp)	2000	15864	7217	1%	2198
childrens' independently homes	1998	15654	789	4%	19841
homes for the mentally handicapped	1999	15760	151	2%	104372
homes for the those with sensory handicaps	1999	15760	12	-1%	1313352
community care centres	1999	15760	75	3%	210136
childrens' hospitals and hospices	1999	15760	13	1%	1212325
medical day centres for infants	1999	15760	56	8%	281433
psychiatric hospitals	1999	15760	76	-1%	207371
dentists	1998	15654	7030	-1%	2227
nursing homes	1999	15760	334	0%	47186
care homes for the elderly	1998	15654	1380	-1%	11344
crisis centres for women	1999	15760	80	25%	197003
independent dispensing chemists	1998	15654	1547		10119
hospitals	1999	15760	136	-2%	115884

Fig. 981 Number of health facilities compared with the size of the Dutch population

Fig. 981 is a table showing 20 different types of public health facilities. By dividing the population by the number of facilities, a potential support base emerges that indicates the number of inhabitants that would be needed to support this type of facility. Due to an irregular, historically determined distribution of the facilities and the factors determining their establishment at a specific location, their distribution is, of course, unevenly concentrated, which, in turn, means that the actual support base, locally, can also vary.

The growth figures for the latest available year, compared with the year prior to that, give an indication of the figures for the years to come, but, in the longer term, they must be calculated more closely in the light of rational expectations of their expected use.

**More outdoor facilities for young children and less (larger) for the elderly**

Fig. 982 and Fig. 983 show the growth of facilities for children and elderly not reflecting the number of users (dependent on growing Dutch population), but rather the number of establishments.

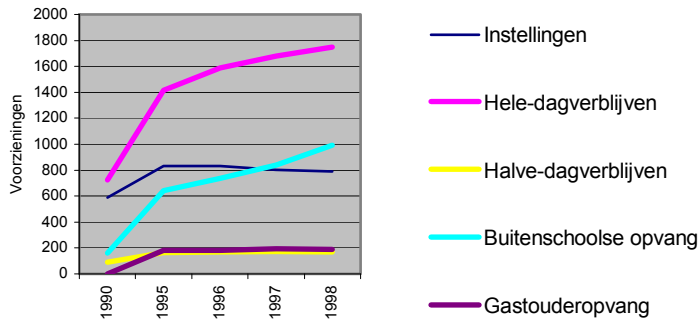


Fig. 982 Development of facilities for children

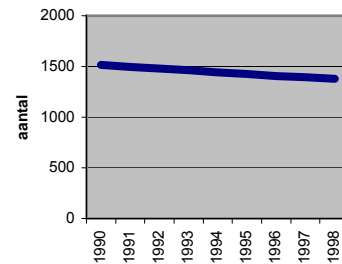
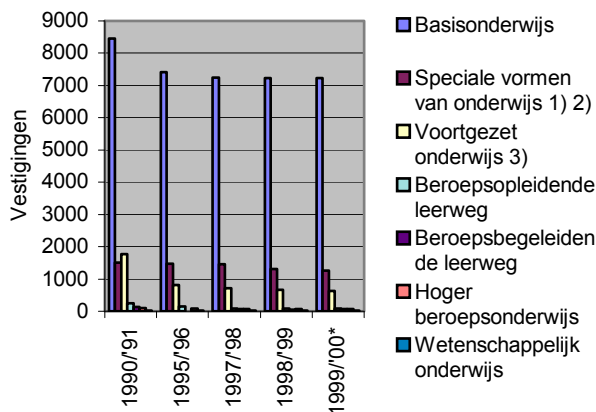


Fig. 983 Facilities for the elderly (care homes for the elderly)

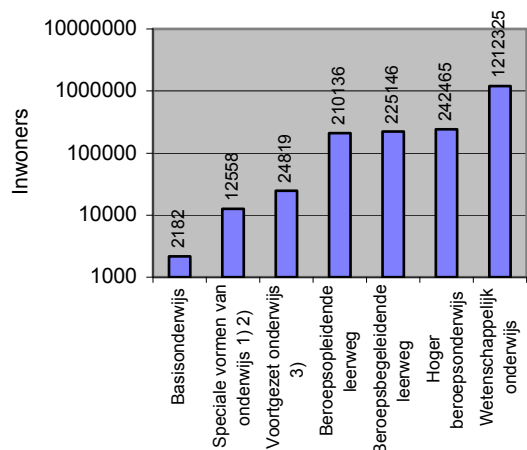
**Decreasing number of schools**



Note 1: Number of departments.  
 Note 2: Including practical education.

Legend top down: primary, special, secondary, technical and vocational training, technical and vocational guidance, higher technical and vocational, scientific.

Fig. 984 Development in the number of schools



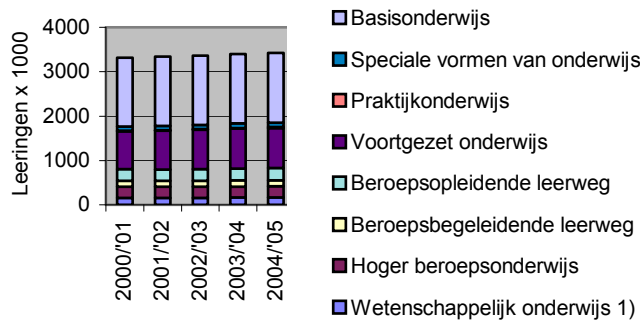
Note 3: University Preparatory Education (vwo), Senior General Secondary Education (havo), Junior General Secondary Education (mavo), Preparatory Vocational Education (vbo) and Learning Path Supporting Education (lwoo)

Fig. 985 The average support base of Fig. 988<sup>a</sup>

From **Error! Reference source not found.** you can learn you need a conurbation of more than 1 000 000 inhabitants for a university, a town of >100 000 inhabitants for technical and vocational schools, a district of >10 000 inhabitants for secondary and special schools and a neighbourhood of more than 1 000 inhabitants for a primary school.

<sup>a</sup> CBS-publication: Education Year Book

### Equal number of pupils



Note 1: Including part-time education.

Fig. 986 Expected number of pupils

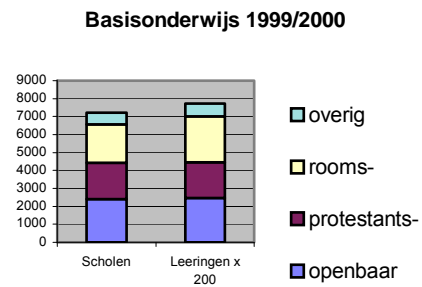


Fig. 987 Establishments and users of primary schools

An equal number of pupils combined with the decreasing number of schools shown in **Error! Reference source not found.**, means a development into larger schools.

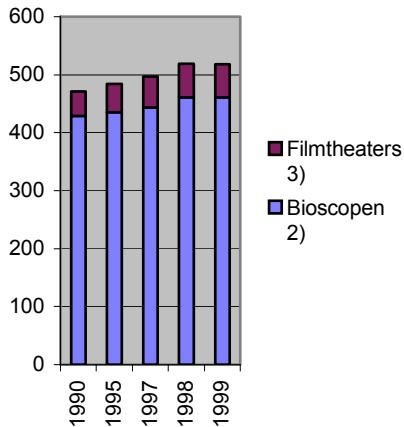
### Less (and larger) schools (at a larger distance)

Establishments for:	year	population	number	growth per year	support base
primary education	1999	15760	7224	-1%	2182
day-release learning path	1999	15760	70	-4%	225146
vocational learning path	1999	15760	75	-7%	210136
higher vocational education	1999	15760	65	-3%	242465
special forms of education	1999	15760	1255	-2%	12558
secondary education	1999	15760	635	-6%	24819
scientific education	1999	15760	13	1%	1212325

Fig. 988 Number of educational facilities compared with the size of the Dutch population

## 6.4.8 Facilities

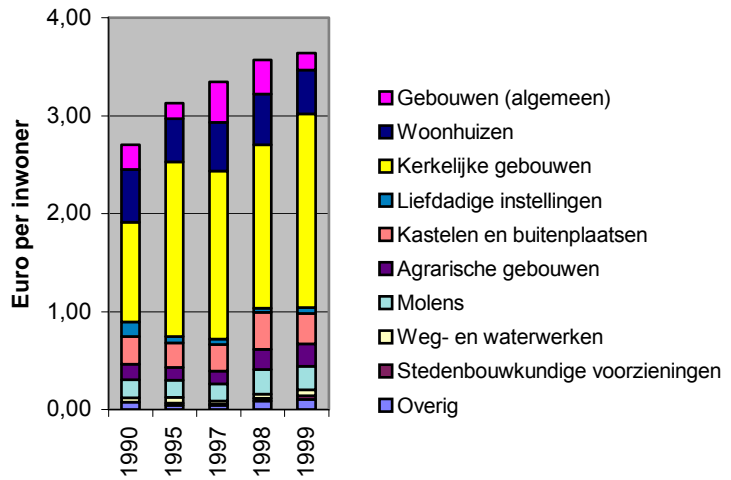
### More cinemas and film theatres, more money for monuments and historic buildings



Note 2: Including two drive-in cinemas  
 Note 3: Excluding non-specifically equipped performance rooms

Source: (Cinemas) Dutch Federation for Cinematography; (film theatres) Dutch Film Theatre Association

Fig. 989 *Cinemas and film theatres*



Legend top-down: general buildings, dwellings, churches, charity buildings, castles and estates, agricultural buildings, mills, civil engineering works, urban facilities, remaining.

Fig. 990 *Expenditures on historic building projects*

Cinemas are just one category of facilities for culture and recreation summarised in Fig. 991. There you can conclude their number did not increase in 2000.



## Facilities for culture and recreation

Establishments for:	year	population	number	growth per year	support base
amusement hall I	1998	15654	420		37272
amenity park	1998	15654	35		447263
ballet theatre	1997	15567	2	-6%	7532471
cinema	1999	15760	461	0%	34187
cabaret theatre	1997	15567	20	2%	761849
casino or lottery	1998	15654	40		391355
creativity centre	1997	15567	63		247097
dance theatre	1997	15567	8	6%	2048304
<b>dance theatre</b>	1997	15567	13	-2%	1173400
zoo	1999	15760	27		583712
film theatre	1999	15760	57	-2%	276495
music and creative arts centre	1997	15567	52		299367
hotel with 1000 over-night stays per year	1999	15760	29053	4%	542
<b>academy of fine arts</b>	1997	15567	244		63800
yacht harbour	1997	15567	400	3%	38918
camping grounds, holiday chalet complexes, youth and group accommodations	1999	15760	3595	-3%	4384
museum	1997	15567	942	1%	16526
mixed museum	1997	15567	19		819321
industrial and technical museum	1997	15567	260		59873
fine arts museum	1997	15567	102		152619
historical museum	1997	15567	491		31705
natural history museum	1997	15567	50		311342
museum of ethnology and folk history	1997	15567	20		778355
<b>musicians' performance stage</b>	1997	15567	50	1%	310514
music school	1997	15567	129		120675
<b>muziektheater</b>	1997	15567	44	4%	355413
theatre for operettas, musicals and revues	1997	15567	8	1%	1954030
horticultural gardens, show gardens and arboretums	1999	15760	104		151541
different types of performing platforms	1997	15567	4	-2%	3736106
place of performance for ensembles	1997	15567	9	0%	1729679
place of performance for improvised music	1997	15567	13	5%	1219356
place of performance for large orchestras	1997	15567	6	1%	2731071
<b>place of performance catering for 300 concerts per year</b>	1997	15567	189	1%	82409
puppet theatre	1997	15567	13	2%	1203642
open-air sports facility	1997	15567	4090		3806
indoor sports facility	1997	15567	2115		7360
<b>theatre</b>	1997	15567	78	0%	200780
playhouse	1997	15567	48	-2%	321413
watersportclub	1997	15567	950	0%	16386
zeil- en surfschool	1997	15567	90		172968
<b>swimming bath</b>	1997	15567	710	0%	21926
swimming bath complex	1997	15567	140	3%	111194
open-air swimming bath	1997	15567	245	-2%	63539
indoor swimming bath	1997	15567	325	1%	47899

Fig. 991 Number of cultural facilities compared with the size of the Dutch population

### Facilities ordered by number, divided by population: support base

Throughout the Yearbook 2001, numerous tables are included that mention the number of established facilities for many organizations and branches. The numbers of 244 types of establishment are summarised in a downloadable Excel sheet<sup>a</sup> allowing to adapt the figures into more recent years or to determine their trend. Divided by the real or expected national population of the relevant year the average support base needed for each type of facility is produced. In *Fig. 992* some of these facilities and their average population support base are mentioned. So, on a next tab of the sheet you can make an average programme for any urban area. However, some areas do have more swimming pools than the average, others more theatres. The deviation from the average offers a profile determining the identity of the place. Many facilities are still missing, such as prisons, police stations, ministries, embassies, surrogate family homes, boarding schools, monasteries and convents, but these can be added.

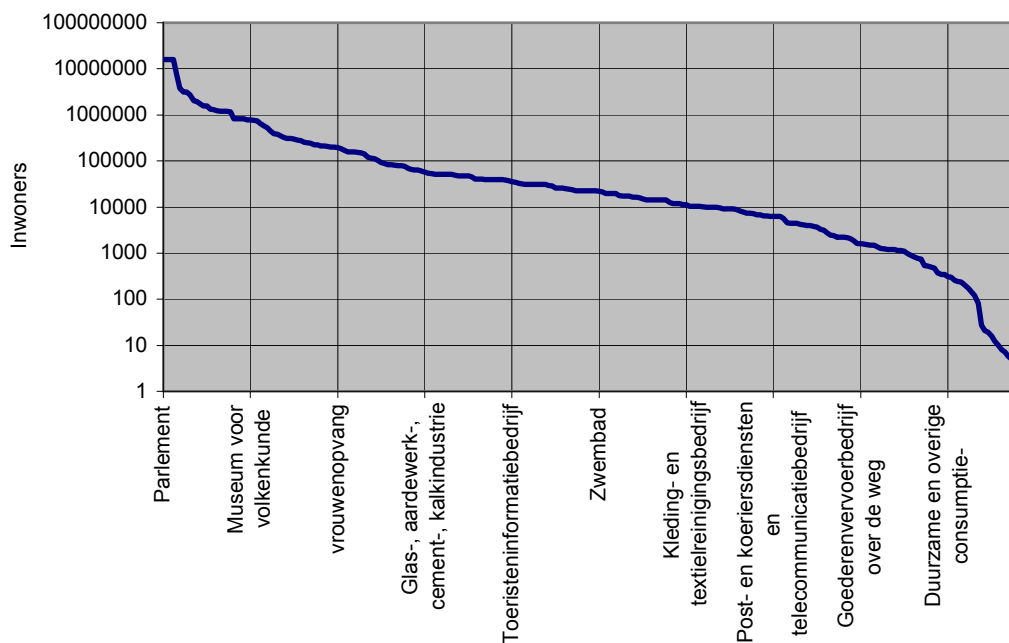


Fig. 992 244 types of establishment ordered by number and their support base shown logarithmically

From this, one can see that, for a population of 100,000 inhabitants, a 'town', most facilities can find a sufficient support base. For those who would like to know more about these urban facilities on the level of a town, *Fig. 993* gives an enlarged picture.

<sup>a</sup> living.xls, downloadable from <http://team.bk.tudelft.nl/> > Publications 2008

## Facilities sustainable on town level

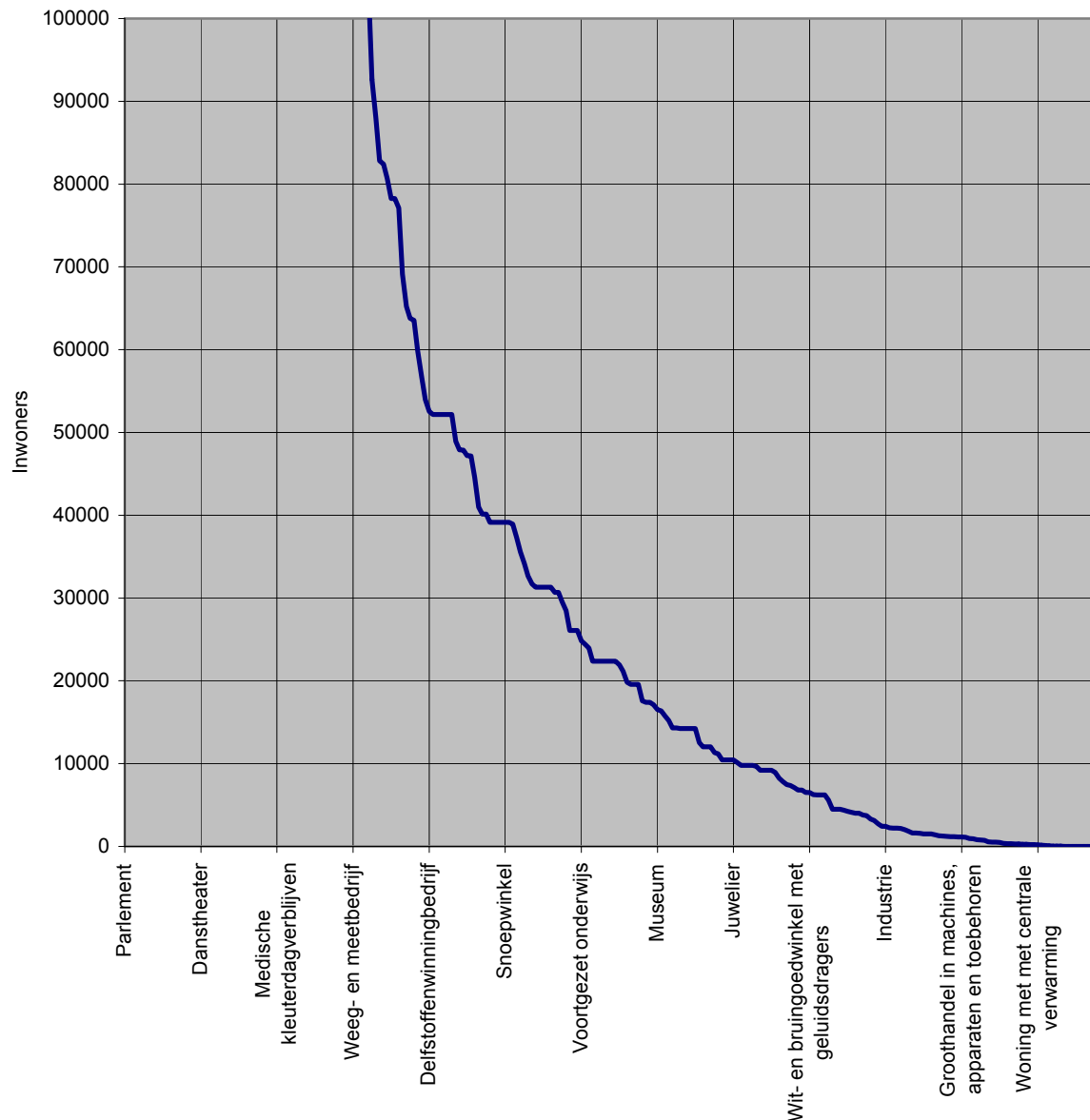


Fig. 993 Ordering of facilities for 100,000 inhabitants

This graph has a certain multi-staged characteristic. In the steep vertical parts, urban growth apparently allows little growth in the level of facilities that it can offer. For populations between 55,000 and 100,000 inhabitants, the number of types of facility hardly increases at all. In the horizontal parts, a little growth can deliver much more facilities. With 25,000 inhabitants (a village or large district) one already has a support base large enough to support half the number of known facilities. A 1000 inhabitants (neighbourhood) give support to 1/3 of the district facilities. To examine that lowest part from 10 000 inhabitants in more detail, Fig. 994 gives an enlarged picture.

### District or village facilities

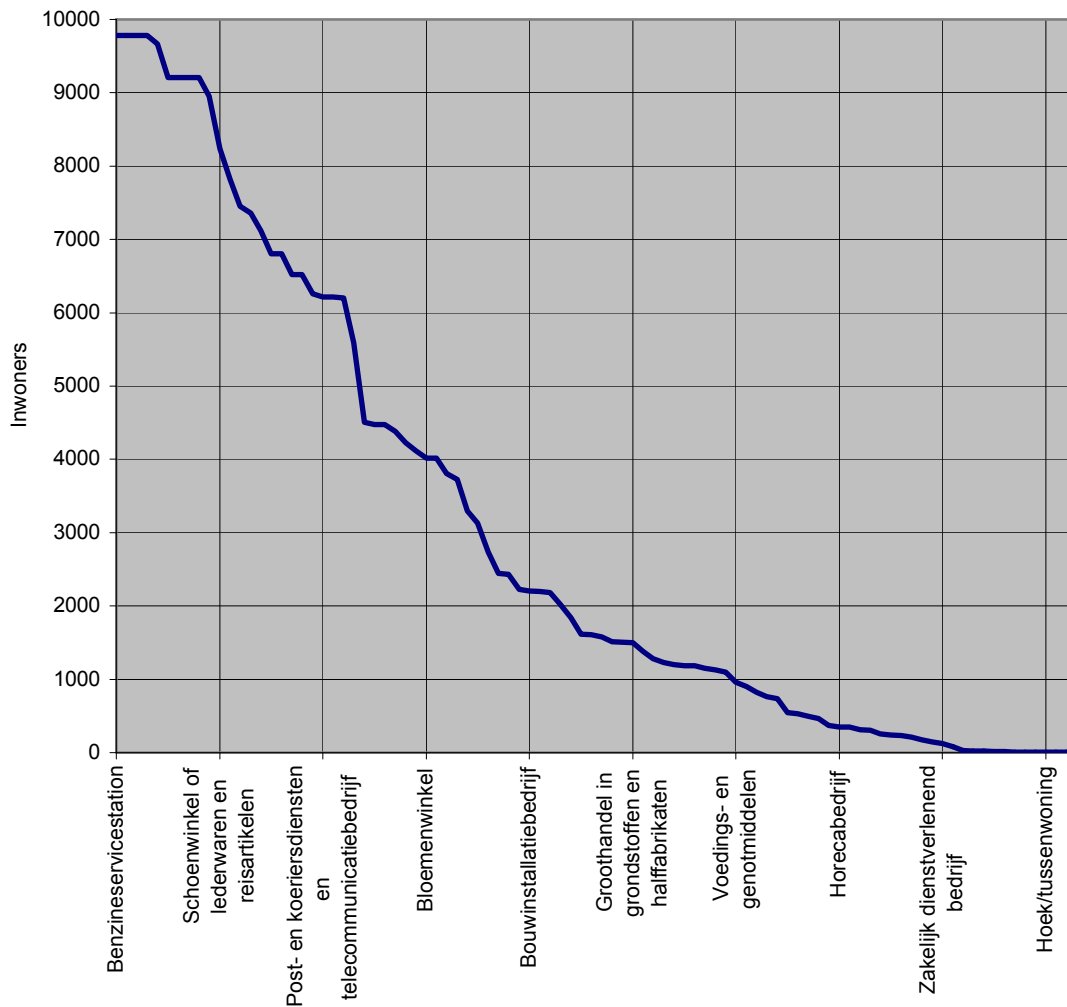


Fig. 994 Ordering of facilities for 10,000 inhabitants.

### 6.4.9 Businesses

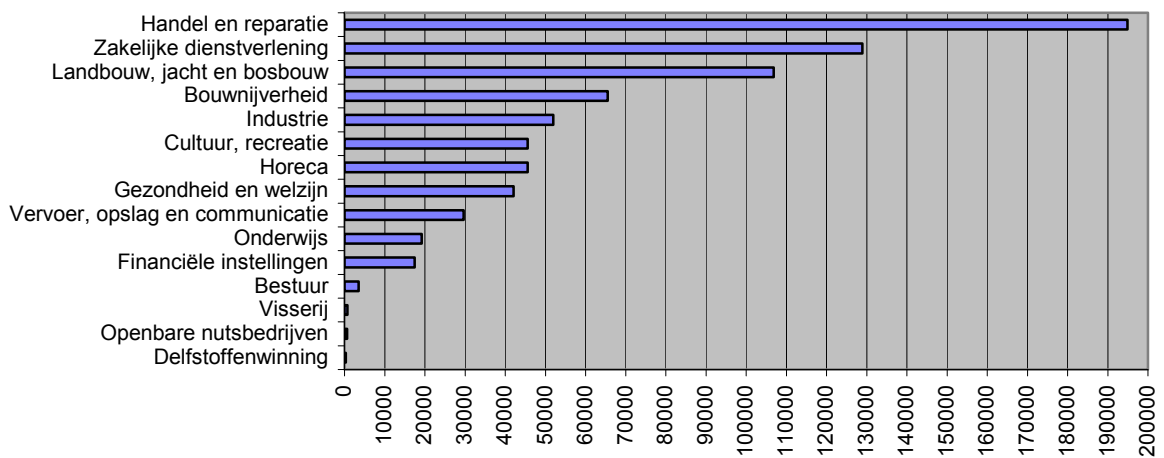


Fig. 995 Business establishments in 1999

On 1st January 1999, there were 752,825 active businesses in the Netherlands, divided into the main categories as shown in Fig. 995. A number of these are more finely subdivided in the paragraphs below.

### Agriculture and Fisheries

In 1999 there were still more than 1 million active agrarian firms in the Netherlands (see Fig. 996).

Establishments for	year	population	number	growth per year	support base
agricultural, hunting and forestry firm	1999	15760	106815		148
fishery firm	1999	15760	745		21155

Fig. 996 Number of agrarian firms compared with the size of the Dutch population

### Larger farms

The increase in the scale of these firms can be seen in Fig. 997.

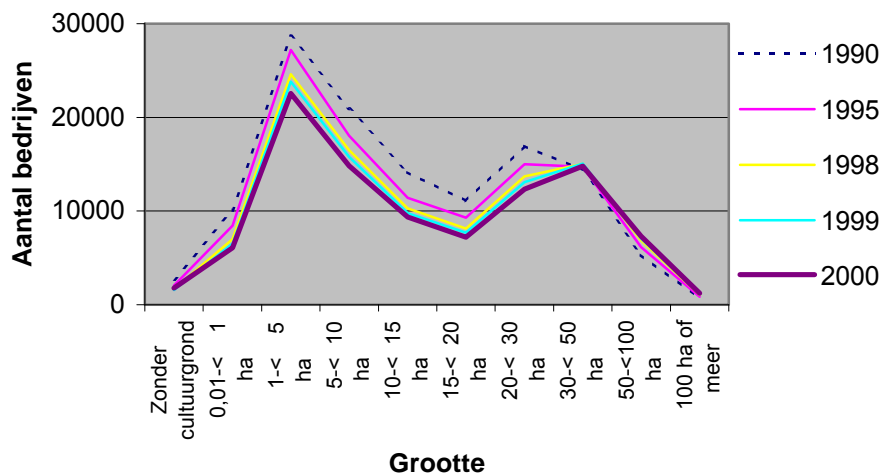


Fig. 997 The increase in the scale of agrarian firms

The scaling-up of individual farms while the surface remains equal implies decrease of the number of farms (Fig. 998), but increase of the number of large farms (Fig. 999).

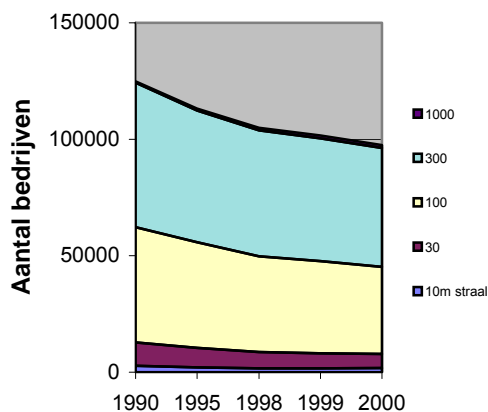


Fig. 998 The development in the order of size of agrarian firms

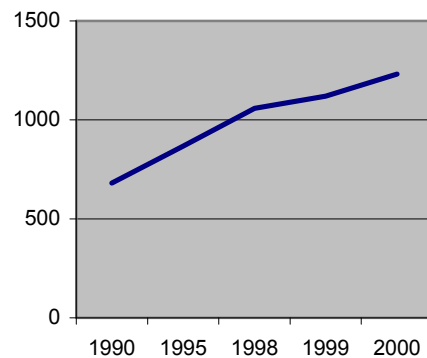


Fig. 999 The growth of agrarian firms larger than 100 ha. (with a radius of 1 km)



## The surface farms need

The surface areas in hectares in these charts have been recalculated into radii used in urban architecture (*Fig. 1000*).

	from m <sup>2</sup>	To m <sup>2</sup>	Radius in m	Number of firms				
				1990	1995	1998	1999	2000
-								
Without arable land			10	2714	2061	1691	1585	1769
0,01-< 1 ha	100	9999	30	10046	8453	7010	6515	6086
1-< 10 ha	10000	99999	100	49556	45253	41076	39613	37355
10-<100 ha	100000	999999	300	61906	56568	54038	52712	51042
100 ha of meer	1000000	9999999	1000	681	867	1058	1120	1231

Fig. 1000 Areas in hectares recalculated into radii used in urban architecture

## Industry

Establishments for:

	year	population	number	growth per year	support base
chemical industry	1998	15654	327	1%	47872
clothing and fur industry	1998	15654	77	8%	203301
electrical apparatus industry	1998	15654	390	0%	40139
food-processing and drinks industry, tobacco processing industry	1998	15654	891	1%	17569
furniture and related industries	1998	15654	382	-3%	40980
glass, earthenware, cement and chalk industry	1998	15654	276	3%	56718
industry	1998	15654	6433	1%	2433
leather, leather goods and footwear industry	1998	15654	41	-7%	381810
machine and apparatus industry	1998	15654	915	3%	17108
metal products industry	1998	15654	1093	4%	14322
office-equipment and computer industry	1998	15654	24	-8%	652258
paper (goods) and carton (goods) industry	1998	15654	203	15%	77114
publishers, printers, reproduction	1998	15654	654	-1%	23936
rubber and synthetic-material processing industry	1998	15654	351	1%	44599
textile industry	1998	15654	178	-5%	87945
transport vehicles industry	1998	15654	332	-3%	47151
wooden, cork, and cane goods industry (excluding furniture)	1998	15654	194	5%	80692

Fig. 1001 Number of industrial branches compared with the size of the Dutch population

## Building Industry

Establishments for:

	year	population	number	growth per year	support base
building company	1998	15654	31459	1%	498
building company specialised in finishing off buildings	1998	15654	8514	4%	1839
building company specialised in <i>b&amp;u</i> , <i>gww</i> , excluding excavation	1998	15654	14268	0%	1097
building company specialised in preparing building sites	1998	15654	1095	3%	14296
building company specialised in hiring out building machinery and personnel	1998	15654	479	-1%	32681
building company specialised in installation	1998	15654	7103	-1%	2204

Fig. 1002 Number of companies in the building industry compared with the size of the Dutch population

## Retail and inland Trading

Establishments for:

	year	population	number	growth per year	support base
florists	1998	15654	3900		4014
bookshops	1998	15654	1100		14231
building material retailers	1998	15654	1300		12042
computer retailers	1998	15654	500		31308
pet shop	1998	15654	1500		10436
<b>diy retailers</b>	1998	15654	3900		4014
chemists	1998	15654	1700		9208
<b>chemists selling medical goods, perfumes and cosmetics</b>	1998	15654	2100		7454
<b>durable consumer goods and other forms of consumption -</b>	1998	15654	50500		310

<b>Establishments for:</b>	<b>year</b>	<b>population</b>	<b>number</b>	<b>growth per year</b>	<b>support base</b>
cycle shops	1998	15654	2300		6806
audio and amplification equipment retailers	1998	15654	700		22363
glass, porcelain and earthenware retailers	1998	15654	700		22363
greengrocers	1998	15654	2200		7116
wholesalers	1998	15654	61496		255
wholesale suppliers of business requisites and packaging	1998	15654	2524		6202
wholesale suppliers of raw materials and semi-fabricated goods	1998	15654	10420		1502
wholesale suppliers of wood, building materials, iron and metal goods	1998	15654	5727		2733
wholesale suppliers of machinery, apparatus, accessories and parts	1998	15654	13899		1126
wholesale suppliers of non-food consumer goods	1998	15654	21193		739
wholesale suppliers of food, spices and energisers	1998	15654	7733		2024
(textile) handicrafts shop	1998	15654	600		26090
household goods retailers	1998	15654	900		17394
household linen retailers	1998	15654	100		156542
ironmongery (hardware) and tool shop	1998	15654	700		22363
jewellers	1998	15654	1500		10436
jewellers selling costume jewellery	1998	15654	300		52181
cheese shop	1998	15654	600		26090
<b>stationers</b>	1998	15654	2000		7827
kitchen equipment retailers	1998	15654	500		31308
dress fabric retailers	1998	15654	400		39135
lamp and lighting retailers	1998	15654	400		39135
retailers of leatherware and travel goods	1998	15654	300		52181
lingerie retailers	1998	15654	700		22363
furniture shop	1998	15654	1700		9208
<b>furniture shop with home textiles, lighting goods and floor coverings</b>	1998	15654	5000		3131
musical instrument retailer	1998	15654	400		39135
sewing and knitting machine shop	1998	15654	200		78271
opticians	1998	15654	1100		14231
perfumery	1998	15654	300		52181
poulterers	1998	15654	300		52181
health-food shop	1998	15654	300		52181
shoe shop	1998	15654	1600		9784
<b>shoe shop with leatherware and travel goods</b>	1998	15654	1900		8239
butchers	1998	15654	3700		4231
off-licence	1998	15654	1100		14231
sweet shop	1998	15654	400		39135
toy shop	1998	15654	700		22363
sports and camping-gear retailers	1998	15654	1600		9784
supermarket, grocers	1998	15654	3500		4473
tobacconists	1998	15654	1700		9208
textile supermarket	1998	15654	400		39135
<b>textile retailers</b>	1998	15654	9900		1581
garden centre	1998	15654	600		26090
paint and wallpaper shop	1998	15654	700		22363
fishmongers	1998	15654	700		22363
carpet shop	1998	15654	500		31308
<b>foods, spices and energisers</b>	1998	15654	16300		960
<b>shop</b>	1998	15654	66800		234
<b>shop selling glass, porcelain and earthenware; household articles or toys</b>	1998	15654	2300		6806
<b>shop selling durable household goods</b>	1998	15654	3800		4120
photographic shop	1998	15654	800		19568
retailers of medical and orthopedic goods	1998	15654	100		156542
retailers of kitchen apparatus, other electrical goods and audio equipment	1998	15654	2400		6523
interior decorators, general assortment	1998	15654	1300		12042
home furnishing retailers	1998	15654	1100		14231

Fig. 1003 Number of trading companies compared with the size of the Dutch population

**Inland Services**

<b>Establishments for:</b>	<b>year</b>	<b>population</b>	<b>number</b>	<b>growth per year</b>	<b>support base</b>
job centres/employment bureaus for assessing, attracting and selecting personnel	1998	15654	1300		12042
architectural and technical design and drawing consultancy	1998	15654	13200		1186
suppliers of spare-parts and accessories for cars	1998	15654	400		39135
<b>car servicing company</b>	1998	15654	3500		4473
tyre servicing company	1998	15654	200		78271
job pools (job-opportunity projects)	1998	15654	100		156542
garage for industrial vehicles, trailers	1998	15654	800		19568
petrol station	1998	15654	1600		9784
bookkeepers, accountants	1998	15654	13200		1186
cafe	1998	15654	12700		1233
cafeteria, snack bar	1998	15654	10400		1505
bodywork repair firms	1998	15654	1500		10436
catering (w.o. party-catering)	1998	15654	1600		9784
car tyre wholesalers and trade intermediaries (middle men)	1998	15654	300		52181
wholesalers and trade intermediaries in spare-parts and accessories for cars	1998	15654	1500		10436
hotel, b&b (bed & breakfast), conference centre	1998	15654	2500		6262
camping ground	1998	15654	1700		9208
camping ground or holiday chalet park, bungalow park	1998	15654	2800		5591
cantine (incl. contract catering)	1998	15654	800		19568
<b>cantine and catering</b>	1998	15654	2400		6523
hairdressers	1998	15654	11300		1385
testing or checking office	1998	15654	500		31308
dry cleaners	1998	15654	1400		11182
motor cycle retailers	1998	15654	500		31308
private car garages	1998	15654	13000		1204
advertising agency	1998	15654	12200		1283
restaurant	1998	15654	9700		1614
restaurant, cafeteria, snack bar	1998	15654	20400		767
beauty salon, pedicure or manicure	1998	15654	13600		1151
cleaners for buildings and transport vehicles	1998	15654	6400		2446
temporary employment agency	1998	15654	900		17393.55
holiday chalets or bungalow park	1998	15654	1100		14231

Fig. 1004 Number of service-providing firms compared with the size of the Dutch population

**Traffic, Transport and Communication**

<b>Establishments for:</b>	<b>year</b>	<b>population</b>	<b>number</b>	<b>growth per year</b>	<b>support base</b>
inland shipping company	1998	15654	4200	-1%	3727
forwarders, ship-brokers or chartering brokers	1998	15654	1620	-5%	9663
road freight haulage companies	1998	15654	9750	5%	1606
loading, unloading and trans-shipment companies	1998	15654	320	7%	48919
airports and other air transport services	1998	15654	30	0%	521806
air transport companies	1998	15654	10	0%	1565419
storage/warehousing companies	1998	15654	510	2%	30694
pipeline transporting companies	1998	15654	10	0%	1565419
post, courier services and telecommunications companies	1998	15654	2520	11%	6212
travel agencies	1998	15654	1030	-5%	15198
travel organisations (tour operators)	1998	15654	550	0%	28462
taxi firms	1998	15654	2520	-7%	6212
tourist information offices	1998	15654	440	19%	35578
tram and bus/coach companies	1998	15654	290	-6%	53980
land transport service companies	1998	15654	390	8%	40139
water transport service companies	1998	15654	240	9%	65226
weighing and measuring companies	1998	15654	110	-15%	142311
ocean-going shipping companies	1998	15654	510	-9%	30694

Fig. 1005 Number of transport companies compared with the size of the Dutch population

## 6.5 Environment

### Definition

We define environment as *'the set of conditions for life'* (Hendriks 1993). In this definition, both 'conditions' and 'life' can be more closely specified. By means of substitution, more precise concepts of the environment emerge, such as 'the set of physical conditions required for plant life' or 'the set of managerial conditions required for animal life'.

conditions	life
managerial	human
cultural	
economic	animal
technical	
ecological	plant
mass/time/spatial	

Fig. 1006 *Substitution possibilities in defining environment*

One can presume a sequence of conditionality in both columns (one cannot imagine management without a culture to carry it; one cannot imagine animal life without plant life, etc.). That becomes an issue as soon as one attempts to weigh the importance of different environments against each other.

### Different environments

However, also *without* the above presumption, these substitution possibilities allow 18 more precise environmental definitions to be made. We can summarise managerial, cultural and economic conditions as 'societal conditions' and the remaining ones as 'physical conditions'. In this way, the number of environmental definitions is reduced to 6. Plant and animal life-forms can be summarised as 'non-human life-forms' (12 environmental definitions), but they can also be more precisely distinguished in the five 'kingdoms'<sup>a</sup> currently recognised in biology, with *homo sapiens* as the sixth category, bringing the number of environmental definitions up to 42. This figure increases further, if we define a species-specific environment for every species.

### Physical conditions for human life

The current environmental definition of 'physical surroundings of society' (more or less according to Udo de Haes in Boersema, Peereboom et al. (1991) ) is just one of the environmental definitions identified above.

Environment is the physical, non-living surroundings of society in reciprocal relationship



Environment is the set of conditions for life

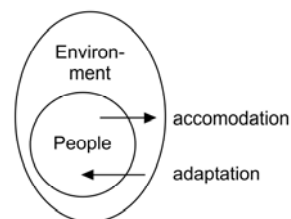


Fig. 1007 *Environment according to Udo de Haes*

Fig. 1008 *Environment in technical sense*

Udo de Haes' formulation can be expressed as a technical definition, by reducing it to 'the set of physical conditions for human life'. However, by doing this, the 'mutual relationship' between physical surroundings and society becomes less 'causal' than those postulated as a *condition* for human life. In

<sup>a</sup> Formerly only plant and animal worlds were distinguished. Nowadays, next to these two, are also disitnguished 'monera' (bacteria without nucleus), 'protocistan' (single celled organisms with nucleus) and fungi (moulds); see: Margulis, L., K. Schwartz, et al. (1994) *The illustrated Five Kingdoms; A guide to the diversity of life on earth* (New York) Harper Collins College Publishers ISBN 0-06-500843-X.

other words, an asymmetry is assumed in the 'relations' between society and the physical environment.

After all, one cannot imagine people, let alone a society, without physical surroundings, but one can imagine physical surroundings without people. A physical environment is thus a technical *condition* for human and societal life. Because of this, a specific physical environment is not the *cause* of one or other form of human life<sup>319</sup>, such as physical determinism at the end of the last century would have led one to believe<sup>a</sup>. Human beings adapt themselves to existing conditions (adaptation) or change physical conditions (accommodation) exploring its possibilities, but they can not surpass its boundary conditions<sup>320</sup>.

## 6.5.1 Conditions

### Conditions determine what is possible

Technical conditions are related to what is possible, while causal relations have a bearing on what is probable within that possibility. After all, what is probable is, by definition, also possible, but not everything that is possible is also probable. So, there are improbable possibilities. One cannot *predict* these, so one has to *design* them.<sup>321</sup>

In the same way as the set of probable futures is a subset of possible ones, the set of causes is a subset of conditions. Every cause is a condition for something to happen, but not every condition is also its cause (a last added condition for something to happen). So, there are more conditions than causes, often operating as (*ceteris paribus*) suppositions hidden in causal reasoning. Economy can be studied as long as the dykes do not burst, that is such a hidden supposition (a technical condition not discussed) of economic reasoning. In everyday life we are not aware of the many background conditions making life possible.

### Conditions making other conditions possible.

The foundation of a house can be a condition for that house, but in the same time not its cause. The cause may be an economic one. On its turn a house can be a condition for a household (it can create the *possibility* of a household) but in the same time not causing it. According to the technical definition of environment the house belongs to the environment of the household making a household possible like the foundations belong to the environment of the house on their turn making the house possible. So, there can be a sequence of conditions making each other possible and a design is summing up these technical conditions in a drawing.

### Design makes possible, not probable

The above argumentation gives an exact indication of what the responsibility of the designer is, in contrast to that of the researcher. If (s)he designs a home, (s)he must not do it in a way that presumes its occupancy by a specific type of household - that would be an encroachment on the freedom of choice of the future occupants – her or his design must keep possibilities open for its occupancy by different sorts of households.

The same sort of dilemma exists in ecology. It is not always possible to forecast where a certain ecosystem will come into existence. Many subtle factors and initial conditions determine its emergence. We cannot *cause* an ecosystem. We only can create the *conditions* under which a set of ecosystems can exist, while others can not.

### Environmental problems

With this conditional environmental definition, *environmental problems* are simply '*missing conditions for life.*' These problems now can be specified further in a technical sense (see Fig. 1006), by specifying 'conditions' (physical or social) and 'life' (human or other).

For the other forms of life, human beings have become a plague, the cause of many environmental problems. But it is also dangerous for the species itself. In a life time the human population has doubled. The agricultural surface is in danger to be halved by desertification, erosion and

<sup>a</sup> The rise and fall of determinism in the spatial sciences around the change of the 20th century, is clearly described in Claval (1976) *De geschiedenis van de aardrijkskunde* (Utrecht) Het Spectrum.

contamination. It will decrease even further if we use its products as fuel for our cars. So, you can count on a quarter of the grain area per person compared to the conditions a century ago. The productivity per ha. increased more than twice, but that progress stagnated (see Fig. 1009). Many environmental problems seem marginal compared to that doom scenario.

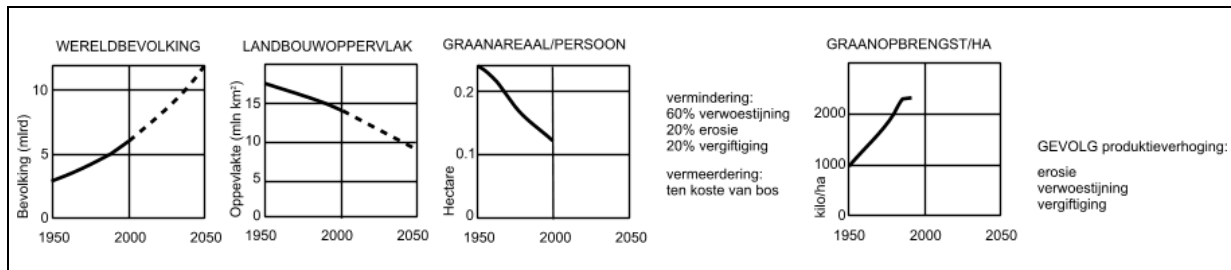


Fig. 1009 *Doom scenario: increasing human population, decreasing agricultural surface*

Using the technical definition chosen here, environmental problems are easily definable as missing conditions for life, and environmental regulations as actions designed to provide for them. These do not have to be the same as the eventually lost conditions, they also can be new conditions.

### Creating new conditions instead of restoring old ones

For a technical definition environmental measures do not need to be directed only on restoring an earlier situation (that is often an illusion by the actual human population), they can also create new life-sustaining conditions (see 6.5.6, page 571). This perception of environmental problems distinguishes designers from researchers. The relations between organisms and their surroundings (including that of the human society and its physical environment) can still be only very partially understood. However, they do not need to be completely understood to restore lost conditions, and to create new ones.

### Taking away the causes is not enough

In addition, many environmental problems cannot be solved any more by removing the cause. We cannot return any more to the situation of 10,000 years ago. At that time, there were an estimated 3 million people on earth and at least 50,000 species more than there are now. And, because we cannot go back, we have to do more than just maintain the old environmental conditions. We *have* to create new ones.

### Diversity of conditions

What is meant by 'conditions' and 'life', can turn out to be different when put into practice. For example, the abiotic conditions for plant life are contained in an environmental concept that is different from those for animal life. In particular, the construction of ecological connections creates new abiotic conditions for certain forms of animal life. Viewed from their predominantly botanical understanding of the environment, the authoritative plant ecologists Westhoff and Van Leeuwen (see page 396), value separation more than connection by 'ecological infrastructure'.

One can define abiotic, biotic, technical, economic, cultural and managerial conditions for different forms of plant, animal and human life (see Fig. 1006). General technical environmental definitions of these different substitutions form just as many environmental concepts, in which apparently conflicting opinions about environmental problems and regulations are brought to the fore.

### Conditional conflicts

It is thus impossible to talk about 'the environment' in general, and to put a general stamp of 'environmentally friendly' on one or the other regulation. Every interference with the surface of the earth increases the possibilities of the one species, to the detriment of other ones.

In agriculture, for instance, we create optimal conditions over enormous areas of land (by fertilisation, hydraulics, etc) for a few plant species, with the result that, with such strong competition, every other species is eliminated. In urban architecture, we optimise in favour of the human species and, within that, for each location, according to certain societal categories. Thus, for each intervention, we must specify which environment we are talking about.



## Urban design providing human conditions

In that perspective, we can now define urban design and architecture as supplying, research- and design-based conditions for *human* life by constructing buildings and organising space (whether or not on a larger scale than that of a single building). *Urban and architectural problems* consist of the (future) absence of those conditions. The aim of *urban and architectural research* is to draw attention to, anticipate or formulate in a programme these (missing) conditions. Therefore, it includes not only anticipatory, explanatory and problem-indicative research, but also design research and effect analysis *beforehand* (ex ante) and evaluating research *after* completing the construction (ex post). The aim of *urban and architectural design* is to present these conditions in a realisable spatial relationship.

## Probable, possible and desirable conditions

Environment is the set of conditions for life in general. *Ecology* is the research into the *probability* of these conditions, and *technical ecology* is the (design related) research into their *possibility*. *Environmental planning* is the provision of conditions for life in general by means of research, design and policy (of course, as far as these can be appreciated by human beings), viewed from the higher scale levels to the lower ones (*an inward-directed approach*). In a similar way, *environmental technical design* is viewed from the lower scale levels to the higher ones (*an outward-directed approach*).

## Anthropocentric and ecocentric viewpoints

With respect to the environment, two standpoints, one of them *anthropocentric* and the other *ecocentric*, can be discerned. The first standpoint should view every aspect from the point of view of human beings (nature as part of culture, see Fig. 1010), and the second one, from the point of view of 'nature' (culture being part of it). As 'nature' is a human concept, the debate between anthropocentrists and ecocentrists, that flares up once in ten years or so, invariably veers in favour of the anthropocentrists. Thus, an '*ecocentric standpoint*' includes only that part of the anthropocentric standpoint that attempts to distance itself from human biases (*έποχη*, epochè) in depicting and organising the environment (the conditions for life). Due to this, the concept 'anthropocentric' has, in fact, become useless, because as long as animals and plants are unable to speak an understandable and convincing language, every standpoint is, by definition, anthropocentric.

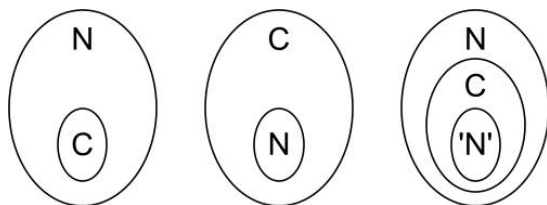


Fig. 1010 Culture (C) and nature (N)



Fig. 1011 Conditional or operational approach

## Operational and conditional action

There are *direct* requirements for human life which, if missing, cause loss of comfort or even the death of people, and *indirect* requirements (such as the existence of plants and animals) that, should they be missing, would adversely affect these direct requirements. The existence of direct requirements for life is thus linked to indirect requirements and, in turn, these are linked to requirements that lie even further away (*conditional links*).<sup>a</sup> For example, for many organisms, the necessary existence of oxygen in the air is, itself, indirectly dependent on the existence of photosynthesis by plants. It is these indirect requirements that are often either easier to influence by *conditional* design or (if they have been irretrievably lost) by providing a new form, than to 'tackle' the missing direct requirement *operationally* as being the 'cause' of the problem (see Fig. 1011).

<sup>a</sup> The theory of conditionality is elaborated in Jong, T. M. d. (1992) *Kleine methodologie voor ontwerpend onderzoek* (Meppel) Boom, translated and extended in English in Jong, Taeke M. de (2006) *Suppositions of imagination, boundaries of design* (Zoetermeer) <http://team.bk.tudelft.nl/> Publications 2006.

A quiet study room can be a requirement for studying. Noise from neighbours leads to the problem that this direct requirement for studying is destroyed. Indirect conditions that can restore this direct requirement can, in this case, be: adopting a complementary living rhythm (so that the noise occurs at times when no one is studying), thick walls or quiet neighbours. Noise from neighbours can thus be solved in more ways than just by 'removing the cause'.

### Interference of conditions

By providing missing direct requirements (to solve environmental problems) one can, in addition, adversely affect other (mostly indirect) conditions. In building a house, one provides, in a direct way, requirements (an 'environment') for human life, but, by so doing, one adversely affects the environment for other life forms and thereby perhaps the indirect conditions for human life. Thus, not only living requirements, but also environmental measures (the provision of certain conditions), are conditionally linked with each other.

For example, to save energy, there is no sense in letting sun enter the house if that house does not stand in the sun, but, in reverse, there is. If the last-mentioned condition is not met, then it would be senseless to provide the first-mentioned requirement. Environmental measures can become each others' conditions or restrictions, without, however, also being each others' direct cause.

### Conditional sequence

Environmental problems (missing conditions) have a conditional link with each other in this way. After all, one environmental problem can facilitate another one, without directly causing it. Eliminating the direct causes (operationally) without analysing the conditions, followed by creating (conditionally) all related requirements for success has often be shown to be ecologically counterproductive.

For example, one cannot bring a manure-polluted drainage ditch back to its original state by stopping the manure pollution as Nienhuis (1993) and Hekstra, Strien et al. (1993) show. In the short term, manure pollution is irreversible. The same sort of problem occurs in medical science: a complaint appears to have a direct cause, but the true cause may lie in shortages elsewhere in the body, so that, unexpectedly, one of the conditions of the body that would otherwise ensure that this sort of complaint does not manifest itself, is not met.

*Environmental strategies* are combinations of environmental regulations, such that they enable and even strengthen each other, both in the time taken and in the sequence of requirements, without creating new problems. *Environmental tactics* is one of the locally or temporarily (politically, culturally, economic, technically) adapted effects of the strategy to the various situations.

## 6.5.2 Emissions

In this section, a number of technical aspects of environmental hygiene are brought to the fore that are important for making short reports on environmental effects and environmental policy plans. There is much literature about this subject primarily summarised in Boersema, Copius Peereboom et al. (1991) to be completed with recent figures from RIVM (2001).

Environmental hygiene, spatial planning and nature conservancy are policy sectors concerned with the unwanted side-effects of human activities. In spatial planning and nature conservancy, in the first place, this has to do with the mechanical effects such as management, disruption, and small and large interventions in nature and space. Environmental hygiene is mainly concerned with material and energetic effects, among others, on materials, people, other organisms, systems and entire geographical areas, including nature reserves.

### A chain of impacts

In order to be able to estimate the unwanted side-effects of all sorts of activities in a given location, beforehand, it is best to divide these activities into living, traffic, nature and agriculture, businesses and incidental activities. These categories can be subdivided into a multiplicity of activities for which, for each activity, emission factors are known. By multiplying these factors by the number of inhabitants, jobs, or km<sup>2</sup>, one can gain an impression of the emissions. This emission is dispersed by air, water,

the ground or other dispersion agents, and eventually has a negative effect on materials, people or other organisms. These can be summarised in the following diagram:<sup>322</sup>

economic activity---->	direct effect of emission ---->	indirect effect of transmission ---->	end-effect, exposure
<b>SOURCES</b> (page 553)	<b>EMISSIONS</b> (page 555)	<b>DISPERSED BY</b> (page 559)	<b>OBJECTS</b> (page 563)
1. Homes 2. Traffic 3. Agriculture 4. Businesses 5. Incidents	1. Inorganic 2. Energetic 3. Mechanical 4. Information 5. Potential emissions	1. Air 2. Water 3. The ground 4. Food chains 5. Transport	1. Materials 2. People 3. Other organisms 4. Systems 5. Locations

Fig. 1012 *The chain of environmental effects*

In this table, no account is taken of unwanted socio-economic side-effects. All that is given is a checklist to assess the environmental effects. The nature of sources, emissions, dispersing media and objects is dealt with in more detail, respectively, in pages 553 - 563.

By estimating the expected emission, transmission, immission and exposure, one can make a report of the environmental effect for an activity or for an entire area. However, in such a report, no policy will still have been formulated to restrict these effects.

**A policy to restrict environmental effects**

A policy of that kind must weigh-up the unwanted side-effects against the useful effect of the intended activity, or of the situation that has come into being, which can then be expressed in an environmental policy plan. A similar consideration occurs due to standardisation. Standards to reduce the damage that many objects suffer due to different human activities, originate in these objects. Initially, it can be established where the limits of damaging influences need to be set, in order to prevent that particular object from suffering an adverse effect.

**Standards**

This can lead to quality standards being set for the ground, water and air, that, in turn, lead to the setting of limits for emissions from a wide range of activities. Finally, one can bring about changes in the harmful activities themselves by linking the processing, the product, or the particular establishment as a whole, to standards and regulations. These are summarised in Fig. 1013<sup>323</sup>.

STANDARDS, applied to:			
the source	the emission <----	the dispersing medium <----	the object <----
product standards processing standards	emission standards - emission ceilings	quality standards	exposure and immission standards
EXAMPLES OF NON-NUMERICAL STANDARDS ('Policy starting-points')			
'Avoiding at the source' (of the emission)	'Combating at the source' (of the emission) 'Best technical means' 'Most practical means'	'standstill' principle	'no effect' 'no adverse effect'
EXAMPLES OF NUMERICAL STANDARDS			
Lead content of petrol	max. 99.2 metric ton CO <sub>2</sub> per year in the Netherlands	average % of oxygen in the water	EPEL value

Fig. 1013 *Standardising to reduce adverse effects*

All standards contain a policy-based consideration of the useful effect of various activities compared with their unwanted side-effects. This is an economic consideration, which is examined further in Section 6.5.5, page 568.

## Sanctions

This standardisation, intended as a feed-back system on human activities in order to prevent negative side-effects, must, of course, be achieved by sanction possibilities.

The Environmental Management Law offers the integral legal framework to accommodate these standards. The international, national, provincial and municipal environmental policy plan can play an important role in this. Whether the standards in the environmental policy plan must be adapted beforehand (by a licencing system), or afterwards (by environmental accountancy) is not yet of importance for the technical aspects of environmental hygiene. In both cases, these remain the same.

## Sources of environmental stress

For the registration of emissions in an area, more facts about the sources are necessary. They can be gained according to Fig. 1014 (a further elaboration of Fig. 1012)

Sources	Subdivision
1. housing, temporary-stay recreation	1.1 households 1.2 encroachment onto public space 1.3 public green areas
2. traffic, infrastructure	2.1 cars and other petrol-powered vehicals 2.2 routes used for transporting dangerous substances 2.3 railways and other electrically powered routes 2.4 shipping 2.5 airways 2.6 cables and pipelines 2.7 beam transmissions (e.g. for radio and tv)
3. nature agriculture, forestry, nature recreation	3.1 natural areas 3.2 forestry 3.3 arable farming 3.4 glasshouse cultivation (incl. mushrooms) 3.5 open-air horticulture and fruit growing 3.6 animal husbandry, fisheries
4. business, day recreation	4.1 mineral exploitation 4.2 historical manual skills 4.3 industry 4.4 public utility companies 4.5 building industry 4.6 services
5. incidental activities	

Fig. 1014 *Overview of the sources*

In 1977, the total emissions for all provinces in the Netherlands were estimated by means of collective registration, supplemented by individual registration. For example, for Gelderland, the emission registration for the four most important emissions gave the picture of Fig. 1015<sup>324</sup>.

gram per day	Carbon monoxide CO	Sulphur dioxide SO <sub>2</sub>	Nitrogen oxides NO <sub>x</sub>	Hydrocarbons C <sub>x</sub> H <sub>y</sub>	per:
Housing	12	4	6	13	inhabitant
Traffic	200	8	54	48	inhabitant
Nature		869	32	690	km <sup>2</sup>
Glastuinbouw	362	1346	317	43	job
Glasshouse cultivation	107	5	5	35	job
Firms	180	588	266	393	job

Fig. 1015 *Four important emissions per source category*<sup>a</sup>

The figures given above are clearly out-of-date, but the type of table made for different years provides comparative material for assessing policy. For the benefit of an initial global reference for emission factors for a particular area, one should use a more recent version of such figures (<http://arch.rivm.nl/environmentaldata/>).

### Combustion emissions and other types of emission

Emissions occur due to the processing of fuels or raw materials. This causes combustion emissions and process emissions, respectively. Energy saving could lead to a significant reduction in combustion emissions. The following table gives some insight into the relation between both types of emission during the 1970s.<sup>325</sup>

		Combustion emissions	Process emissions	total
1Tg = 1000 000 000 kg = 1 mln ton		g/inhabitant/day	g/inhabitant/day	Tg/year*
carbon dioxide	CO <sub>2</sub>	8920	90	46.04
carbon monoxide	CO	286	49	1.71
nitrogen oxide	NO <sub>x</sub>	108	6	0.58
sulphur dioxide	SO <sub>2</sub>	70	8	0.40
hydrocarbons	C <sub>x</sub> H <sub>y</sub>	33	25	0.30
aerosols, dust, soot		20	0.13	
hydrated calcium sulphate (gypsum)	CaSO <sub>4</sub>		427	
salt	NaCL		67	0.34
sulphuric acid	H <sub>2</sub> SO <sub>4</sub>		22	0.11

Fig. 1016 *Relation between combustion emissions and process emissions*<sup>b</sup>

<sup>a</sup> calculated from the Emission Registration for Gelderland (1977) and LEI statistics (1977)

<sup>b</sup> CBS statistics 1978; Emission registration 1974/1981; Hermans and Hoff 1982

## Types of emission and environmental stress

To estimate the nature of the end effect and the manner of dispersal, the emissions need to be distinguished from each other, either by source or by groups of source, as in Fig. 1017 (an elaboration of Fig. 1012).

Types of emission	Subdivision	Examples
1. inorganic emissions	1.1 metallic 1.2 other inorganic	copper, lead, mercury CO, SO <sub>2</sub> , NO <sub>x</sub>
2. organic emissions	2.1 pure 2.2 halogenic 2.3 oxygenic 2.4 nitrogenic 2.5 sulphuric 2.6 metallic 2.7 other inorganic	methane, toluene, benzene vinyl chloride alcohols, esters amino acids thiols organic mercury organic phosphorus
3. mixtures	3.1 complex mixtures 3.2 aerosols 3.3 solid waste 3.4 microbic	BZV (biological oxygen consumption), CZV (chemical oxygen consumption), kjeldahl (method for measuring nitrogen) fly ash, industrial waste tetanus, botulism
4. energetic emissions	4.1 heat 4.2 sound 4.3 radiation, magnetic 4.4 radiation, radioactive 4.5 magnetic field	cooling-water traffic, industry light, infra-red, ultra-violet, radar, ether waves alpha-, beta-, gamma- high-voltage transmission lines
5. mechanical emissions	5.1 disturbance 5.2 small interruptions 5.3 substantial interruptions	treading on the ground, mowing, vibrations, up-rooting, digging ploughing, vandalism, clearing ground, building explosions
6. information emissions	6.1 visual 6.2 olfactory 6.3 others	horizon pollution bad smells misleading sounds
7. potential emissions	7.1 emission reduction 7.2 risk 7.3 variation in emissions	cloth filter, sedimentation plant, lpg (liquid propagaz) tank, (waste) storage day-night variations

Fig. 1017 *Types of emission*

Further information is given briefly below about a few of these types of emission.

### Material emissions

Metallic inorganic compounds can produce accumulating pollution that is heavily poisoned. For water pollution, mercury and cadmium, in particular, and compounds of these substances, are on the black list. The black list is a European list of the most dangerous substances for the environment that may not be released in any quantity at all.

The other inorganic compounds include: *carbon monoxide, sulphur dioxide, nitrogen oxides, halogen compounds, phosphates and arsenic*. These include, therefore, the quantitatively most important emissions and the majority of the combustion emissions. Special attention is given to a few of these below.

*Carbon monoxide (CO)* is formed when combustion is incomplete. It is a poisonous, colourless and odourless gas. The total amount of CO throughout the world remains surprisingly constant, despite increasing (industrial) production. In addition, CO occurs naturally in the atmosphere, due to the oxidation of hydrocarbons. However, CO is effectively oxidised to CO<sub>2</sub>, so CO only remains in the atmosphere for 0.1 of a year.



*Sulphur dioxide (SO<sub>2</sub>)* is a colourless gas with a suffocating smell. It irritates the mucous membranes and the lungs, but, apart from this, it is not so damaging. It occurs naturally in the atmosphere, among other things as a result of volcanic eruptions. A high concentration of SO<sub>2</sub> is indicative of pollution by tiny particles (aerosols).

Sulphur dioxide is extracted from the atmosphere by oxidation to SO<sub>3</sub>, which reacts with water to form sulphuric acid (H<sub>2</sub>SO<sub>4</sub>). Together with other substances, this is the cause of acid rain.

This is the reason why more and more lakes in Canada, Scandinavia and the Netherlands have become sterile, why forests have lost their vitality or have been declared as dead, why heather has been taken over by grass, why wood and agricultural yields have declined and why our cultural heritage has been irreversibly harmed. A small part of the SO<sub>2</sub> is immediately washed out and absorbed by vegetation and water. The time that SO<sub>2</sub> stays in the lowest part of the atmosphere is in the order of a number of days, and, under certain conditions, a number of hours.

*Hydrogen sulphide (H<sub>2</sub>S)* is a smelly, poisonous, inflammable gas, that irritates the eyes and the respiratory tissues. It is released into the air by natural bacterial decomposition processes, but also by many industrial processes. It disappears from the atmosphere via oxidation to SO<sub>2</sub> or due to the activities of certain bacteria. It remains in the lowest part of the atmosphere from a few hours to a number of days.

*The nitrogen oxides (NO<sub>x</sub>, i.e. NO, NO<sub>2</sub> and NO<sub>3</sub>)* originate from nitrogen and oxygen in the air at temperatures higher than 800°C. NO occurs in the first instance, but as it cools, it is partly transformed in the atmosphere to NO<sub>2</sub>. NO is a colourless gas that, in itself, is not harmful.

The reddish-brown NO<sub>2</sub>, on the other hand, is much more harmful due to its irritating effect on the mucous membranes. NO<sub>x</sub> is finally oxidised to nitrate and stays for about five days in the atmosphere. NO<sub>x</sub>, in combination with hydrocarbons, can form all manner of new compounds in the atmosphere that can contribute to 'photo-chemical smog'. This results, among other things in '*PAN*' (*peroxide-acyl-nitrate*) and *formaldehyde (HCHO)*.

Of the inorganic halogen compounds, it is mainly the compounds with fluorine (F) and chlorine (Cl) that are important.

*Hydrofluoride (HF)* is a very corrosive, poisonous fluid, that, due to its low boiling point (19.4°C), is easily emitted as a gas (of importance as a potential emission from storage sites). It is a cumulative poison, i.e. it builds up inside organisms.

*Chloride gases* enter the atmosphere mainly as a result of industrial accidents and leakages, as an insecticide, or due to burning plastics.

The phosphates are mainly important in water pollution. They can cause such an enormous richness of food in the water that it becomes devoid of oxygen.

## Organic emissions

*Organic ammonia (NH<sub>3</sub>)* occurs especially in the bio-industry. It stays for about seven days in the atmosphere.

Of the *hydrocarbons* in the atmosphere, only about 15% originate from human activities. However, this amount has another composition, and is concentrated in a relatively small area. The natural hydrocarbons come from the decomposition of organic material and emissions from plants, especially certain trees. Above pine forests and citrus cultivations a haze can often be seen due to photo-chemical smog formation. The majority of hydrocarbons disappear from the atmosphere due to photo-chemical smog formation. They remain for quite a long time in the atmosphere; methane (CH<sub>4</sub>), for example, remains there for about four years.

However, the length of time that these substances remain in the atmosphere is dependent on reactivity. A total of 150 different hydrocarbons have been identified in car exhaust gasses. They are released mainly due to incomplete combustion and by evaporation. From the many different hydrocarbon compounds, a number of examples are given below.

The group of *halogenic hydrocarbons* contains a large number of black-listed substances, such as alpha-, beta-, gamma- *hexachloro-cyclohexane*, the PCBs (polychloro-biphenyles) and *PCTs* (polychloro-terphenyles), hexachloro-benzene, hexachloro-butadiene, pentachloro-phenol and trichloro-phenol.

The chlorofluoro-hydrocarbons (CFKs, such as freon) belong to the halogenic hydrocarbons. They are used in cooling systems, as a propellant in spray cans, and are not poisonous in themselves. However, they can harm the ozone layer of our atmosphere, so that there would be no resistance any more to ultra-violet rays.<sup>326</sup>

The **other material emissions** include complex mixtures, aerosols, dust or particulate matter in the air, solid waste and free-coming bacteria, viruses (sick buildings!) or genetic material.

### Mixtures

The complex mixtures include a large number of emissions from mostly organic material that can be largely biologically decomposed, and therefore their exact chemical composition does not need to be known. For these complex mixtures, standards are used such as BZV (biological oxygen consumption), CZV (chemical oxygen consumption) or the Kjeldahl method for measuring nitrogen.<sup>327</sup>

### Aerosols

The aerosols are tiny solid and/or fluid air-borne particles that have such a slow rate of fall that they can be considered to float or drift. They originate naturally, enter the atmosphere through combustion processes, or are formed in the atmosphere by chemical reactions (e.g. by photo-chemical smog). Rain or snow is formed by condensation and sublimation, respectively, on the aerosols. Compared with the air over oceans, the average pollution of the air over rural areas by aerosols is ten times higher. Above small towns, air pollution by aerosols is 35 times higher, and above large cities 50 times higher than over the oceans. In unfavourable situations, this figure can increase to 4000 times or more.

### Fine dust or particulate matter (PM)

Fine dust or particulate matter in the air (particles  $<10\mu\text{m}$  notated by  $\text{PM}_{10}$ ) of different substances could be dangerous for human health. That is why the European standard from 1<sup>st</sup> of January 2005 is maximally  $40\mu\text{g}/\text{m}^3$  average *per year*, with maximally 35 times per year a *24-hour average* exceeding  $50\mu\text{g}/\text{m}^3$ . Enduring exposition seems to be more dangerous than short exposition, but in 2005/2006 many Dutch building projects were rejected by jurisdiction based on measurements and prognoses of exceeding the short 24-hour average exposition standard. However, a distinction should be made in more dangerous fine (0.1 - 2.5  $\mu\text{m}$ , deeply penetrating the lungs) and less dangerous coarse mode (2.5 - 10  $\mu\text{m}$ ) particulate matter and their composition concerning health-effects varying over Europe.

*<sup>a</sup>Inorganic ions nitrate, sulphate and ammonium sum to 34% of PM mass and the measured organics from combustion processes up to 2%. Rough estimates of the traffic contributions of these two fractions vary from 30% to 60%. In the framework of the project 'Health effects of particles from motor engine exhaust and ambient pollution - HEPMEAP', a unique European collaboration between toxicologists and epidemiologists, ambient particulate matter (PM) was collected at various sites across Europe during the periods November 2001 and March 2003. The HEPMEAP project studies the relation between the composition of particulate matter, and the toxicity and health effects. Besides strong similarities, PM samples from these various locations/sources show substantial differences in chemical composition. For example, samples from the rural location in Northern Sweden were highly dominated by organic matter, most likely originating from wood combustion.'*

In The Netherlands natural salt spray particles from the sea vary around  $7\mu\text{g}/\text{m}^3$  along the West Coast until  $3\mu\text{g}/\text{m}^3$  in the Eastern part of the country. So, since August 2005, dependent on the location from West to East a municipality may subtract 7 to  $3\mu\text{g}/\text{m}^3$  from the measurements to reach the maximally 35 days exceeding the  $50\mu\text{g}/\text{m}^3$  24-hour average.<sup>b</sup>

If you subtract this harmless part of particulate matter, the European picture becomes less threatening (see Fig. 1018).<sup>c</sup>

<sup>a</sup> <http://www.rivm.nl/bibliotheek/rapporten/863001002.html>

<sup>b</sup> [http://www.vrom.nl/get.asp?file=Docs/milieu/200508\\_meetvoorschriftluchtkwaliteit2005.pdf](http://www.vrom.nl/get.asp?file=Docs/milieu/200508_meetvoorschriftluchtkwaliteit2005.pdf).

<sup>c</sup> [http://www.tno.nl/tno/actueel/magazine/bouw\\_en\\_ondergrond/2006/juni\\_2006/beno\\_2\\_2006\\_16.pdf?\\_\\_lang=nl](http://www.tno.nl/tno/actueel/magazine/bouw_en_ondergrond/2006/juni_2006/beno_2_2006_16.pdf?__lang=nl)  
[http://www.tno.nl/tno/actueel/magazine/2006/june\\_2006/em\\_2\\_2006\\_18.pdf?\\_\\_lang=nl](http://www.tno.nl/tno/actueel/magazine/2006/june_2006/em_2_2006_18.pdf?__lang=nl)

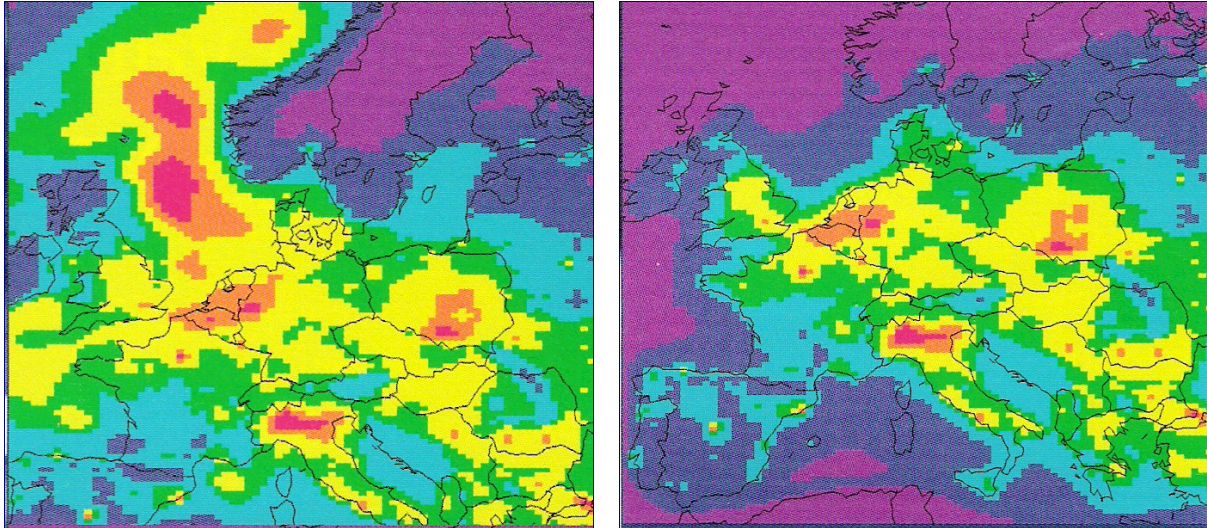


Fig. 1018 Calculated PM10 concentrations with and without salt spray particles in Europe<sup>a</sup>

In 2006 more recent measurements changed the expectation of PM10 values in 2010 dramatically (see Fig. 1019).

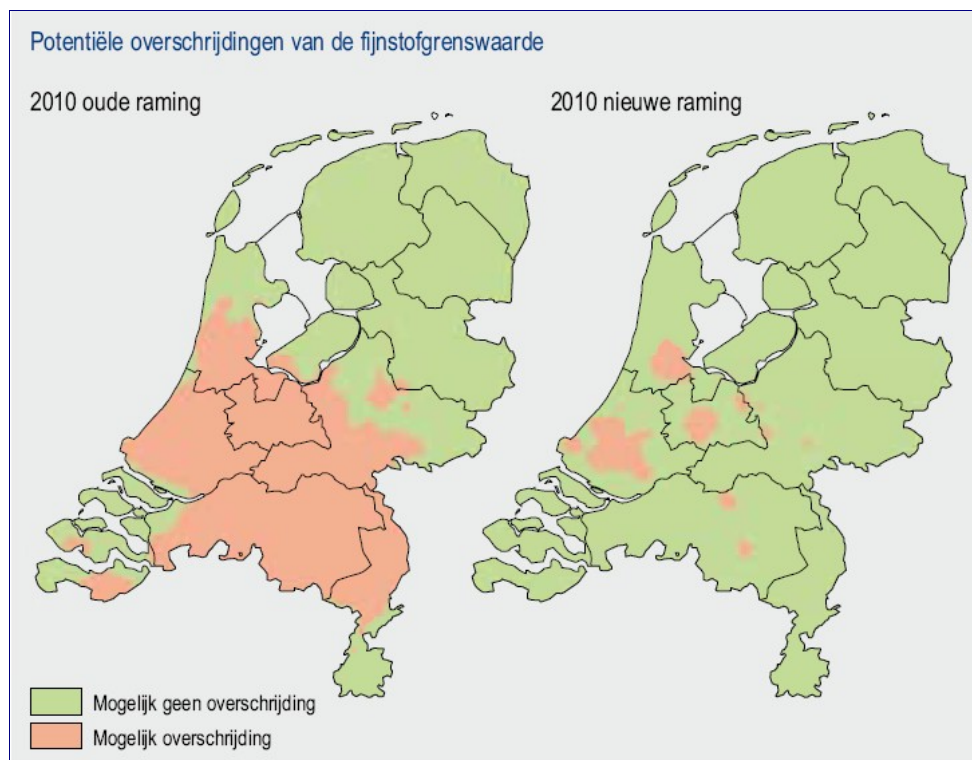


Fig. 1019 2005 (left) and 2006 (right) prognoses of exceeding European standards for particulate matter in 2010<sup>b</sup>

A more precise evaluation of health effects of different PM components may change the imminent social and economic effects of these standards up to now even more. Kuypers (2006)<sup>c</sup> claims plantation can clean the urban air. A tree could take the equivalent NO<sub>2</sub> and PM<sub>10</sub> of a car driving 10 000 km.<sup>a</sup>

<sup>a</sup> LOTOS-EUROS computer model, TNO magazine, june 2006

<sup>b</sup> <http://www.rivm.nl/bibliotheek/rapporten/500093003.pdf>

<sup>c</sup> Woestenburg (2006) Naar een zelfreinigende groene stad in: Het kwartaaltijdschrift van Wageningen Universiteit en Researchcentrum Nummer 2, Juni 2006

### Energetic emissions

Energetic emissions include warmth, sound, electromagnetic and radioactive radiation, and changes in the magnetic field. With the exception of radioactive radiation, in so far as it originates from radioactive substances that are dispersing, this is a form of emission, the spread of which is very predictable. If these emissions occur, it is known that almost all objects in the vicinity will be subjected to immediate exposure. Because of that, in measuring emissions (as in the case of sound), certain aspects of the exposure can already be included. The unwanted side-effects of energy-in-motion emissions can, on the basis of a named characteristic, best be controlled within the framework of spatial planning.<sup>328</sup>

### Mechanical emissions

Mechanical emissions, such as disturbances, small and substantial interruptions, are, within the framework of environmental hygiene, not generally considered to be 'emissions'. They are a part of the working field of spatial planning, 'urban management' and nature conservancy. However, logically and systematically, they fit in with an overview of types of emission and environmental stress, such as that shown in Fig. 1017. These emissions can also be largely controlled using spatial planning regulations.

### Information emissions

Information emissions include all influences that disturb the functioning of our ability to form images by sight, smell, taste, touch, balance, and voluntary movements. They are subjective, difficult to measure, and traditionally belong partly to the working field of spatial planning. However, a lot of research still needs to be carried out in this area. For example, if symptoms of psychiatric illness could be linked to urban living conditions (e.g. in the form of sensoric or motoric overloading or deprivation), then interesting new requirements could be placed on urban surroundings.

### Potential emissions

Potential emissions include emission-reducing regulations, risks<sup>b</sup> and variations in emissions. Emission-reducing regulations and risk management are part of the continuing responsibility of all engineers.<sup>c</sup> The variation in emissions makes it somewhat more complicated to set standards than to fix an average. Local and temporary periods of peak stress are, after all, the most dangerous. Variations in stress can be cyclical, subject to trends, and/or can increase abruptly, in leaps.

## 6.5.3 Transmission

Transmission is especially important for material emissions. It contains the propagation of energetic, mechanical, informational (noise) and potential influences (risk) and of material by air, water, the ground or via food-chains, mainly the territory of specialists and extensive computer programs. Transmission includes the transport, dilution, dispersion, conversion and removal of material in and out of the air, water, ground, food-chains and other relocating systems.<sup>329</sup>

### Air pollution

We will go into the spreading of air pollution the most thoroughly below. In addition, ground and water pollution is partly a result of pollution in the air, so that, also from this view point, priority must be given to gaining a better understanding of air pollution. In this respect, it is important that a distinction is made between vertical and horizontal air movements.

Where there are no vertical air movements in a stable atmosphere, pollution stays at low levels and can become highly concentrated locally. Horizontal air movements are important in predicting where air pollution will occur. For water pollution, especially important are the horizontal displacements, and only in the case of deep lakes or seas do vertical displacements also play a role. The displacement of ground pollution is largely dependent on ground water currents, and possibly on human transport.

### Vertical air movements

The sun acts as the motor for all air movements. Sunlight is partly intercepted by the atmosphere and, especially in the higher layers, warms it up. The lowest layers of air receive their heat mainly from the

<sup>a</sup> Woestenburg (2006) Naar een zelfreinigende groene stad in: Het kwartaaltijdschrift van Wageningen Universiteit en Researchcentrum Nummer 2, Juni 2006

<sup>b</sup> The chance of effects is called risk (popular formulated chance times effect). The risk approach is starting point for standardization and is extensively dealt with in the parallel lecture on security policies (Hale)

<sup>c</sup> Memorandum 'handling risks', published simultaneously with the 'Nationaal Milieubeleidsplan'

surface of the earth, which is warmed up during the day, releasing its heat again by radiation at night. Because of this, the lowest layer of air (to about a height of 10 km), the troposphere, has, in principle, an upwards-decreasing temperature. However, the stratosphere, that lies above it, becomes warmer in its higher levels. If rising air comes into contact with warmer layers of air, it stops rising. There is thus little exchange between the troposphere and the stratosphere, also with respect to air pollution. The troposphere is approximately 10 km high and contains about 80% of the total mass of the atmosphere. This is where almost all weather phenomena occur; this is where the largest warming up and cooling down takes place, and where the air pollution increases and decreases due, respectively, to emissions being released and washed away.<sup>330</sup>

### Polluted air remaining low

Warm air rises until the surroundings become warmer, but, in retaining its own heat content, rising air also cools off due to expansion. This cooling off process amounts to about 1°C for every 100 m that the air rises.<sup>331</sup> An air bubble warmed up by the surface of the earth that is 2 degrees warmer than its surroundings will thus rise 200m if the surroundings of the air bubble stay the same, and it will rise more than 200m if the surroundings become colder.

It is clear that if the lowest part of the troposphere has become relatively warm because of a number of hot days, there will be very little rising air, so that the air pollution will stay below. One can talk then of a stable atmosphere. Especially after the night time cooling off of the lowest layers of air due to radiation from the earth's surface, temperatures, that rise with height, can occur the next morning.<sup>332</sup>

### Inversion

If a chimney doesn't rise above the point where the temperature starts to go down again, as is normal in the troposphere, then the smoke stays held in the lowest layer of air, because the surroundings are too warm to allow the air to rise. Such a situation is called *inversion* (an inverse temperature gradient).

In the course of the day, a rise in temperature in the lowest layer of air can cause the inversion to disappear. However, that does not happen if there are clouds in the sky, or if the rise in temperature is insufficient to make the lowest layer of air much warmer than the layers above it. Because of this, an inversion can last for several days.<sup>333</sup>

### Moisture

The amount of moisture in the air is just as important for the development of vertical air movements. Moist warm air, rising from the surface of the earth, cools down by expansion and, above a certain height, loses its moisture by condensation. This condensation produces heat that causes the air to rise further and then to cool down further, thereby producing more condensation. The height at which condensation begins forms the flat underside of the cloud layer.<sup>334</sup> Thus, because of the heat development that then occurs, a loss of moisture can cause the air to rise even more.

### Horizontal air movements

At ground level, the air is warmed up the most in the tropics and the least at the poles. Because the air in the tropics is continually rising, warm air moves northwards in the higher layers, partly due to it cooling down over the subtropics, and then it sinks to the lower layers of air in our latitude (see Fig. 218). The continually sinking air at the poles produces a cold northerly wind, that meets the warm humid air masses from the south in our latitude. This results in a lot of condensation and precipitation in our latitude, in cold polar air wedging its way under rising warm air until this too is heated up by the earth's surface. Because of this, the polar front in our latitude produces a much more turbulent weather pattern than elsewhere.<sup>335</sup> On the one hand, this is good for the mixing and dispersion of air pollution, but it also makes air pollution less predictable than in tropical or polar climates.

### Southwestern winds

The sun rises in the east because the earth rotates eastwards. The atmosphere rotates with the earth. Therefore, in contrast to polar air masses, tropical air masses have a strong eastward impulse. As they move towards the north, this eastward tendency persists, so that tropical air in our latitude comes mainly from the southwest. As relatively stationary polar air masses move southwards, they become increasingly confronted with the earth's rotation and thus have a tendency to move westwards in relation to the earth's surface. Because of this, in our latitude, cold polar air masses come mainly from the northeast.<sup>336</sup>



## Polar front

The eastward tendency of the tropical air and the westward tendency of the polar air, when they meet in our latitude (the 'polar front'), cause air movements that circulate in an anticlockwise direction.<sup>337</sup> In low pressure areas (depressions), into which the winds always blow, this is usual. That means, for example, that the winds are southerly if a depression lies to the west of the Netherlands, and northerly if the depression lies to the east. Based on this, a number of frequently occurring circulation patterns can be identified for Europe, and their frequency over the years can be established statistically. From this, statistical indicators have been formulated of expected weather types, and these can be applied to dispersion models for air pollution.

## Coastal circulations

A very frequently occurring type of circulation, on a smaller scale, occurs systematically in coastal regions. Because of the alternation between day and night, there is also an alternation here between sea and land winds. A sea wind occurs along the coast when the sun shines strongly and, due to this, the land warms up faster than the water, causing a difference in air pressure.<sup>338</sup> At night, the land cools off faster than the sea, causing a wind to blow from the land, seawards.

## Turbulence

Based on climatological factors, regularity in wind direction, as mentioned above, applies to flat, open spaces, but not to built-up urban areas. Very many smaller circulations occur there that are summarised by the concept 'turbulence'. Where there are eddies behind buildings, the only way of predicting turbulent air movements in these urban areas to any extent, is to place maquettes in wind tunnels, on a revolvable platform. To carry out very exact tests on them, such maquettes must be built by specialists, because it is very important to simulate the roughness of the material and it is impossible to position gauge points on a normal maquette.<sup>339</sup>

## Mathematical models of wind circulation

For sources in relatively open areas, mathematical models can be applied. One can distinguish pollution-point sources, such as chimneys, line sources, such as main roads, and surface sources, such as an industrial sites. The most frequently used dispersion model is the Gaussian Plume model, of which there are a number of variations. In addition, there are 'grid models' and 'trajectory models' as described in KNMI De Bilt (1979). In the Gaussian Plume model, it is assumed that air pollution is dispersed perpendicular to the direction of the air movement, according to a statistical distribution. Grid models divide the space into box-shaped units, by means of a co-ordinate system whereby the input and output is calculated per box.

Trajectory models are based on forward-moving box-shaped units of air, each unit of which has input and output values.<sup>340</sup>

## Concentration of air pollution

The concentration of air pollution substances can be shown in three different ways.<sup>341</sup>

- volume/volume (unit ppm)
- weight/weight (unit ppm)
- weight/volume ( $\mu\text{g}/\text{m}^3$ )<sup>a</sup>

RIVMs national gauging network for air pollution was drastically modernised in 1985 and now comprises 68 gauge points. In addition, TNO manages ten more points, and the provinces and municipalities 80 and 20, respectively.

## Deposition

Apart from the dispersion of air pollution, the fall-out (deposition) of particles and the washing out of air polluting substances in rainwater, chemical changes in the air pollution itself also play a role in the total transmission of air. However, not much is yet known about these processes. Most of what is known concerns photo-chemical smog, in which mainly the chemical composition of combustion emissions changes under the influence of light.

<sup>a</sup> The term  $\mu\text{g}/\text{m}^3$  stands for one million gram (microgram) per  $\text{m}^3$



## Smog

Photo-chemical smog mostly occurs as a result of 'ground inversions' caused when the lowest layers of air cool down faster than the layers of air above. Because of this, condensation occurs in the lowest layers of air (fog), and, as there is an inversion, the pollution also stays trapped in these layers. Aerosols serve as nuclei for condensation and the drifting drops of water catch the remaining pollution, whereby all manner of reactions occur. The formation of ozone (O<sub>3</sub>) under the influence of sunlight can play an important role in these reactions. However, compared to water pollution, chemical and biological reactions in air pollution do not play such a large role.

## Water pollution

Pollutants enter water by deposition from the air, by draining out of polluted ground and by direct discharge. Thus, in the pattern of currents in a river, one can find pollution-surface sources on the surface of the water, line sources along the banks and point sources at the location of the discharge. Apart from these sources of pollution, the following means of 'removal' also play a role:

- extractions, removal to groundwater, to tributaries;
- reactions of a physical, chemical or biological nature.

Based on this input and output, a balance can be drawn up for each stretch of river. As one can talk here of a one-dimensional current movement, the concentrations can be calculated using rather simple models. However, after 1965, models were developed that could also handle two-dimensional situations (as in shallow lakes, bays and harbours).

## Mathematical models of water pollution

Insight into bio-chemical processes also became more advanced. Before 1965, already, the models took into consideration the deterioration of dissolved oxygen and the decomposition of organic material from waste water. Between 1965 and 1970, the oxidation of reduced nitrogen compounds was also included in the models. Between 1970 and 1975, three-dimensional situations, such as deep lakes and seas, were included in the models. The water masses were thereby divided up into layers (stratification). In addition, the growth and death of algae, and the physiological reaction of organisms to temperature, sunlight and the availability of food materials were described. After 1975, the behaviour of toxic substances in biological processes (among others, their accumulation in the food chain) was researched, as well as their transport on floating particles and sediment.<sup>342</sup> Because of the increasing complexity of the models, it has to be recognised that their reliability is decreasing. For this reason, one-dimensional models are still being used.<sup>343</sup>

## Ground pollution

In chapter 6.6 Soil pollution, page 577 and further you can find a more comprehensive treatment. Here we restrict to some fundamentals. Ground pollutants can be transported in the ground water. They can be held and removed by absorption into soil particles, precipitated by chemical processes and dissolved again, and (partly) decomposed by micro-biological processes, especially in the thin zone that is not completely saturated with water.

The speed, direction and depth of a groundwater current depends very much on the type of soil and the variation in subsoils. In principle, three-dimensional current models are available for this, but these need to be fed with an extremely large amount of detailed information about the subsoils. This information is largely unavailable, so one has to make do with simpler current models. For regional studies, in particular, taking the relatively limited depth of the water transporting systems into account in relation to the extent of the region, a calculation in two dimensions is usually sufficient.<sup>344</sup>

## Absorption

The speed and direction of groundwater currents are, of course, initially dependent on the type of ground. For removing pollution by absorbing it onto the surface of soil particles, the specific surface area of a solid soil particle is important. For clay, for example, this is larger than for sand. The more acid the environment, the more difficult it is for pollutants to attach themselves to the soil particles. Acidity, therefore, leads to some pollution of the groundwater. In addition, of course, as time goes on, the whole surface area can become saturated, so that larger amounts of pollution come to be transported in the groundwater currents. In that case, certain substances can still be precipitated out of the water or dissolved into it again. The solubility of chemical substances is also dependent on the acidity (pH) and on the 'redox potential' (Eh).

## Conversion

Micro-biological decomposition and conversion processes are generally the most effective in the thin zone that is not completely saturated with water. Especially in the transition zone, where the presence of oxygen may or may not still play a role, can anaerobic decomposition processes (without oxygen) be of great significance. Among the well-known micro-biological conversion processes are nitrification, denitrification and sulphate reduction.

## Data

For a quick orientation regarding the possible risks of extending pollution that has appeared on or in the (water) bed, reference can be made to archive information (van Duijvenbooden 1982). Among other sources of information, reference can be made to:

- geological maps
- ground maps
- topographical maps
- hydrographic charts
- geo-hydrological mapping (surface contour charts, seepage/infiltration charts, quality charts)
- geo-electrical mapping
- individual reports and data.

By studying the information listed above, a preliminary insight can be gained of the local direction and speed of the groundwater currents. If information on substances is available, then it is also possible to estimate their transport.

## Points of interest

Attention should be given, among other aspects, to:<sup>345</sup>

- the structure and composition of the soils (clay/peat with low  $k^*$  and high CEC; sand with large  $k$  and low CEC, pH, redox; and the mud and organic-material content);<sup>a 346</sup>
- the geological structure (presence of pockets of sand in contrast to layers of clay, heterogeneities, holes, stratification);
- the hydrological situation (seepage/infiltration, current direction and speed, location of the watershed, drainage or infiltration channels);
- topography (on the basis of height characteristics, gives a first impression of the probable current direction).
- If necessary, extra information can be collected in the field (van Duijvenbooden 1982).

## 6.5.4 Immission and exposition

### Exposed objects

Determining the end effect (see Fig. 1012) is the final and most difficult part of every environmental-impact statement. The first thing that has to be established is which objects situated in the neighbourhood of the environment-damaging activity are the ones on which the effects have to be determined. In this section, the types of object distinguished are materials, people, plants and animals, (eco)systems, or entire areas. When there is no clear prior agreement regarding on which objects the effect has to be reported, there will always be criticism afterwards on the effect report that is delivered. If one already has a list of objects on which one has to report, then the question still remains of which effects have to be reported.

### Damage

If the object is people, then one can still distinguish absolute effects (such as the mortality rate) from gradual effects (such as the illness rate). To be able to view the effects against each other and against the useful effect of an environment-damaging activity, it is desirable, though usually impossible, to quantify it to a common denominator. Of course, especially in the United States, frequent attempts have already been made to express the damage caused by environment-damaging activities in terms of money. The table below pictures this for the Netherlands (1978).

<sup>a</sup>  $k$  and CEC are measures for the adsorption capacity of the soil type. For  $k$  is true: low value means high adsorption. For CEC is true: high value means low adsorption

Damage to	mln.guilders	no. guilders per inhabitant
materials	110	8
health	1000	71
commercial crops and livestock	85	6
lost residential value	1400	100
total estimative damage	2600	185

*Fig. 1020 Damage due to air pollution in the Netherlands estimated in 1978<sup>a</sup>*

### Costs of damage

The most reliable datum in this table is 'damage to materials'. The way in which 'damage to health' is calculated is already indicative of the dubious assumptions that have to be made when expressing this damage in terms of money. The costs of early death were estimated as the (discounted) income that the deceased would have earned had there been no air pollution. The amounts used to arrive at the costs of illness were 'loss of production' and 'the costs of curative care'.

There are, though, three methods of approach for damage due to death:

1. The 'human capital' approach;
2. The 'costs of risks' approach;
3. The comparison with costs made to prevent unnecessary death.

The method used in *Fig. 1020* is the 'human capital' approach. For the second approach, wage differences – that can be interpreted as 'risk surcharge' – are used as the point of departure. To determine the value of a life, the extra wage paid for a 1% higher death risk is, for instance, multiplied by 100. The third approach ought to be based on the amount that the Dutch society is prepared to spend on 'the most expensive patient in the Netherlands'.

For example, a vaccine should not cost more than € 18 000,- per life year gained (NRC Handelsblad 2003-07-06).

### Distinguishing the environmental part of damage

It must be clear that, even if the nature of the effect can be described clearly and unambiguously, it is usually difficult to quantify<sup>347</sup>. In addition, it is difficult to separate the effects of environment-damaging activities from other influences. In this way, the 'lost residential value' in *Fig. 1020* is estimated on the basis of differences in house prices observed in transactions in Rijnmond. However, the house-price differences are also dependent on house characteristics (type of home, house size, year of construction, with garden, etc.) and the characteristics of the district in which the house is located (green facilities, nearby shops, noise levels, accessibility, etc.)

To be able to determine the effect of a home located in a foul-smell zone from these fixed variables, complicated regression analyses and daring assumptions are necessary. Instead of 1.4 billion guilders, a few changes in the assumptions would have given 1.7, 2.4 or 3.3 billion guilders as the lost residential value in the Netherlands.<sup>348</sup>

### Dose-response of living objects

The effect of environmental pollution on living organisms can be shown in the form of a dose-response diagram (Fig. 1021).

<sup>a</sup> Jansen en Olsthoorn (1982), Jansen et al (1974)

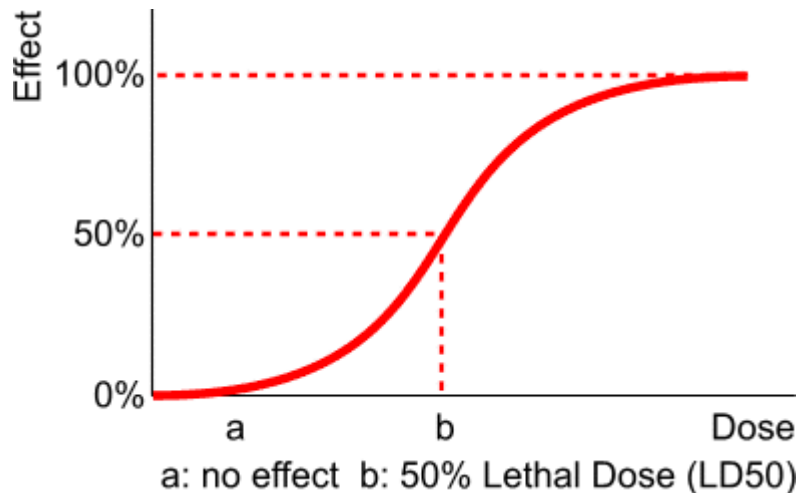


Fig. 1021 Dose-response relation

A similar diagram can be drawn for poisoning a large number of individuals with different doses. The dose that causes death in 50% of the cases, within a given time, is called 'the lethal dose at 50%' (LD50).<sup>349</sup>

It is clear that dose-effect relations are only known for a small number of substances on a small number of organisms. It is, of course, difficult to establish the dose-effect relations for human beings empirically, so there are still many knowledge gaps in this area.

### Material damage

Research has established that the worst damage to materials is brought about by the action of SO<sub>2</sub> on painted steel, galvanized steel and on zinc foil. Research (*Fig. 1022*) was set up by Jansen and Olsthoorn (1982) consisting of:

- Measuring the concentration of SO<sub>2</sub>;
- Determining the exposed quantity of materials;
- Establishing the dose-effect relations;
- Making an economic evaluation of the effects.

In this research, only maintenance costs, the costs resulting from reduced economic lifespan and substitution costs were taken into account. Indirect costs (for example, those resulting from the failure of affected parts) were not taken into account.

The costs listed above were estimated using a number of formulas by which, if the concentration of SO<sub>2</sub> in the air is known, the reduction of the galvanized layer, the length of protection of the paint layer, or the lifespan of the construction part were derived. These sorts of formula, in fact, represent dose-effect relations. Recalculated as costs and added up, it is possible to give a dose-effect relation for the whole of the Netherlands.

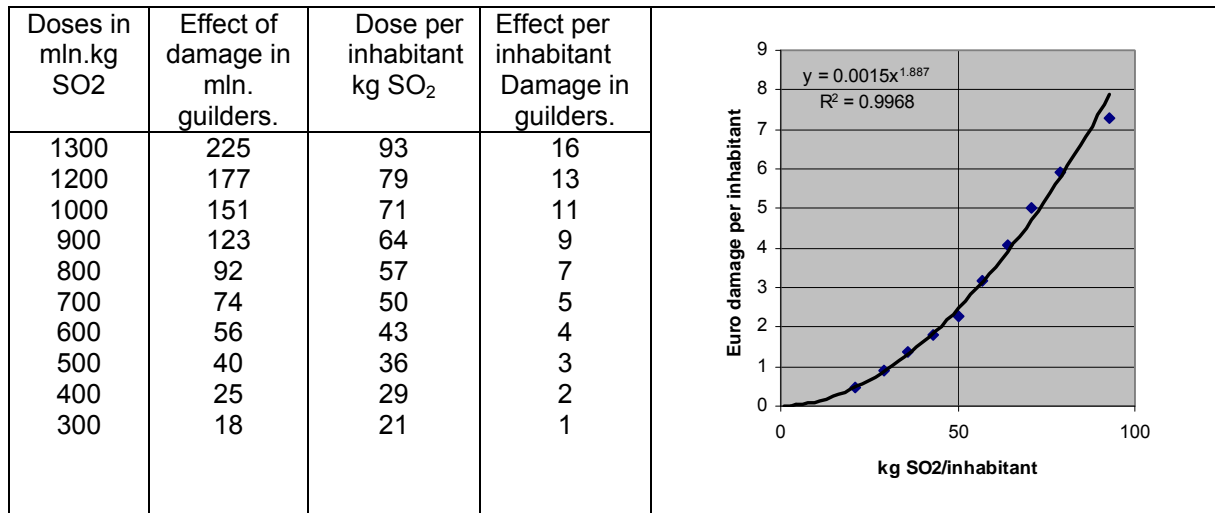


Fig. 1022 Dose-effect relation of SO<sub>2</sub> on a range of metal constructions in the Netherlands (1978)<sup>a</sup>

This dose-effect relation is thus composed of different dose-effect relations that are only related to a certain material part of the damage not including health effects.<sup>350</sup>

### Toxicology of people

For people, the lethal doses of a lot of poisons are known, as well as many of their clinical characteristics and side-effects (the absolute and gradual effects). The branch of medical science that concerns itself with poisonings is 'toxicology' see: Sangster (1987).<sup>351</sup> The process by which humans take up, re-absorb, transform, apportion, store and excrete poisons can be summarised in the following diagram.<sup>352</sup>

Contrary to materials, human beings, animals and plants can develop resistance to repeated exposure to poisons. However, a slow build-up of toxins is equally likely to have sudden, serious consequences. In addition, the effects of different types of pollution can be increased by their interaction. One example of this is evidenced by smokers' increased susceptibility to the adverse effects of air pollution. As a rule of thumb, one can say that if air pollution increases by 10%, the mortality will increase by approximately 1%.<sup>353</sup>

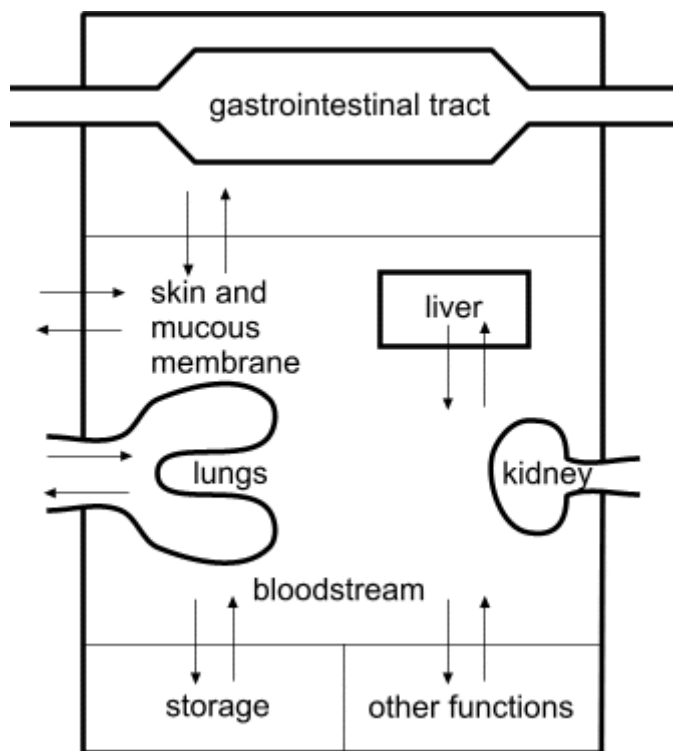


Fig. 1023 Toxicological access routes into the human body<sup>b</sup>

### Historical disasters

As the literature on toxicology is fairly easy to access, we will restrict ourselves here to human exposure to a few historical cases of severe air pollution (Source: KNMI 1979)

<sup>a</sup> Figures per year, calculated according to Jansen and Olsthoorn (1982)

<sup>b</sup> Verberk and Zielhuis (1980)

In December 1930, the narrow and heavily industrialised Meuse valley, in the neighbourhood of Leige, experienced weather conditions, which – for almost a week – hindered the spread of the pollution produced there. The result was that a large number of people became ill due to respiratory problems, and, before the end of that week, 60 people had died. It is not clear whether very high concentrations of sulphur or flurides were the cause of the disaster, because no pollution measurements were taken at that time.

A disaster that has been extensively researched is the one that hit the small town of Donorain in the valley of the River Monongahela in the State of Pennsylvania in the United States in 1948. Also here, unfavourable meteorological conditions, together with the hills that encircle this industrial town, hindered the dispersal of air pollution. The result was that thousands of people became ill, mainly with respiratory complaints and problems with the eyes, nose and throat. During this 7-day period, 20 people died.

Even worse was what happened in London from 5-9 December 1952. The majority of Great Britain was covered in fog at that time. Elderly people in particular became ill, suffering from heart problems or respiratory difficulties, and had to be taken to hospital. Even after the worst period of pollution had subsided, more deaths occurred than was usual for December. The total number of deaths rose to between 3,500 and 4,000 above the usual number of deaths in December. The extremely high concentrations of soot and sulphur dioxide were probably the cause of this disaster

In the Netherlands, air pollution has not led to a *demonstrable* number of deaths (that is something else than calculated decrease of lifetime-expectenace or brain performance), but there were obvious increases in the numbers of both illnesses reported and hospital admissions, such as in the period 26-30 January 1959 and 4-6 December 1962. In Rotterdam, in 1959, the amount of smoke in the open air, and, in 1962, the sulphur dioxide concentrations, reached extremely high levels. In both these cases, too, it was long periods with no wind and bad vertical exchange that caused increasing concentrations of toxins in the air.

### Plants and animals

Hardly anything is known about the extent to which material pollution has caused the disappearance of plant and animal species. For a number of species, such as lichens, a clear link can be made with air pollution. The extinction of plants and animals is largely due to the loss of their biotope. This is mostly caused by light and heavy mechanical interferences, such as agriculture, urbanisation and road building. For instance, lowering the water level of ditches can cause a significant reduction in the diversity of vegetation.

However, a correlation does not always have to be a causal relation. The distance to a farm and the related reduction in agrarian activities can also offer a better explanation for local diversity, even if there is already a correlation with the water levels in drainage ditches. Water levels in themselves can correlate with the distance to the farm, if that farm is situated on higher ground so that the water level in the nearby drainage ditches is deeper than in those further away.<sup>354</sup>

### Systems and areas

The effect of various forms of environmental stress on eco-systems and related geographical areas or utility zones is largely unknown. The effect of the 'mechanical emissions' named in Fig. 1017, such as treading on the ground, mowing, up-rooting, digging, ploughing, clearing the ground, and building, is the easiest to determine.

The vulnerability of different geographical units to light or heavy interferences is recorded on environmental charts. Vulnerability charts are compiled to show the vulnerability for each environmental theme. More will be said about this in the following section. The old objections to environmental charts are, that these divert attention away from the interferences, their alternatives and effects, so that only alternative locations are discussed. These are less of an issue now that the instrument of environmental impact assessment (MER) is available. Although by far not everything is known about the environmental effects on plants, animals and ecosystems, an interesting part of the MER series has been published, entitled: Effect prognoses. Part V: 'Plants, animals and ecosystems'. VROM/LNV (1987)



## 6.5.5 Creating standards

### Effect-directed norms

In the previous sections, the unwanted side-effects of the activities summarised in Fig. 1014 are described. Effect reports can be compiled along these lines. However, in this section, the focus is no longer on ascertaining the effects, but on the policy-wise reduction of those effects

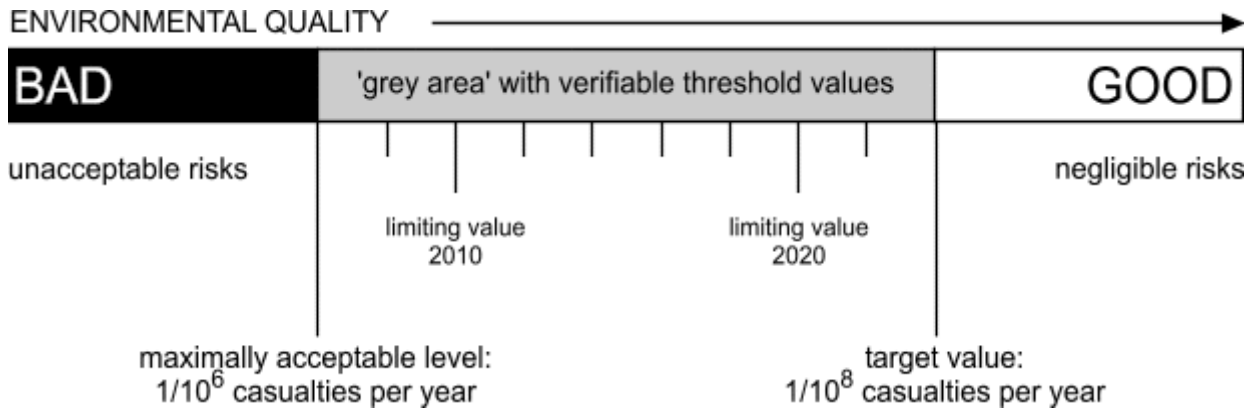


Fig. 1024 Threshold, limiting and target values

### Accepted risks

The starting point is the end effect on people, ecosystems and economic functions, as shown in the previous diagram. In the totality of risks, to human beings an individual chance of dying of  $10^{-5}$  per annum is accepted by government; the *maximal acceptable level of risks*. For each single activity or substance, the maximal acceptable level is  $10^{-6}$  per annum.<sup>355</sup> For illness (effects with a threshold value) comparable levels are given, as well as for disturbance resulting from noise or foul smells. For ecosystems, a similar sort of approach is developed. The maximal acceptable level is achieved when the concentration of a substance is the same as the calculated concentration, whereby protection is offered to 95% of the species in an ecosystem. However, in many cases these norms appeared to be unattainable (RIVM 2003).

### Negligible effects

It is assumed that below 1% of this maximal acceptable level the effects are negligible. This marks the target value of all emissions and environmental effects: the value that should be eventually achieved<sup>356</sup>. Between both levels there is a so-called 'grey area' within which targets for a certain period can be formulated using verifiable threshold values<sup>357</sup>.

As soon as these threshold values have gained the legal status that they may not be exceeded, they are referred to as 'limiting values'<sup>358</sup>. If such values may only be exceeded when reasons are given, then they are referred to as 'guide values'<sup>359</sup>. Before these values are fixed, one can refer to them as environmental quality targets<sup>360</sup>, and after that, as environmental quality requirements<sup>361</sup>.

### Target values

As a target value can only be reached in the longer term, for the shorter term, one can fix lower limiting values for what must be achieved during a certain year as an interim step towards the year in which the target value has to be achieved. An example of environmental quality targets is the table of target and limiting values of priority substances from the first National Environmental Policy Plan (see Fig. 1025).

substance	target value	limiting value	average	concentration around the sources	% reduction for the benefit of the target value	% reduction for the benefit of the limiting value	reference
trichloro-ethene surface water	50 0,1	50	0,65 2,0	80	35-40 95	35-40	IMP 1987
tetrachloro-ethene surface water	25 0,1	2000	1,0 3,5	30	20 98		IMP 1987
benzene	1	10	2	40 (185)	97,5	75	base doc MP
phenol	1	100	0,008	2	50		
etc							

Fig. 1025 Target and limiting values of priority substances and the percentages of necessary reductions in emissions that result from this. Amounts in  $\mu\text{g}/\text{m}^3$  for air (or  $\mu\text{g}/\text{l}$  for water)<sup>a</sup>

### Time to reach target values

Regarding the priority substances, after thoroughly studying the effects of each substance, target values will be prepared in a 'basic document' for the general environmental quality of water, ground and air. In the grey area, for phasing the policy, limiting values must be fixed that indicate how far the protection will extend during the period agreed. This takes place on the basis of an economic consideration.

### Weighting costs and environmental quality

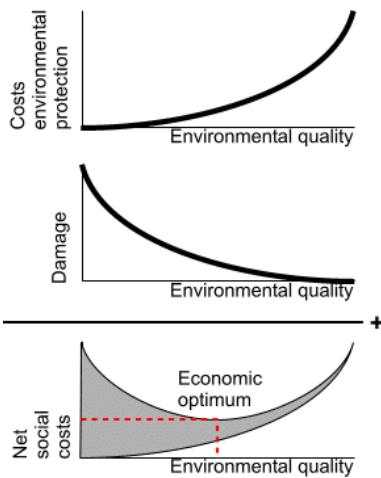


Fig. 1026 Net societal costs after deducting environmental damage

The costs of this protection increase progressively with the quality of the environment that we want to achieve in this way. It is not always possible to achieve an immediate recovery of environmental quality to the target value. One only has to think of the amounts of money involved in soil decontamination to understand that complete recovery of environmental quality not only financially, but also technically, takes time to achieve.

Limiting values include a consideration whereby the damage to exposed objects is weighed against the economic interests associated with the activities involved.

In so far as this damage can be expressed in terms of money, this consideration is rather simple. After all, the costs of the damage can be added to the costs of protecting the environmental quality for every protection level imaginable. From this, for a certain threshold value, an economic optimum is obtained.<sup>362</sup>

### Threshold values

However, in section 6.5.4, it became clear how open to interpretation the concept 'damage' is, and how dependent this is on the value we place on the protected objects. In addition, the graph does not run as continuously as in Fig. 1026. Locally, a small additional protection effort can suddenly save a species of fish. These sorts of quality aspect are therefore expressed as verifiable threshold values. For example, a threshold value can be established for the oxygen content of water, above which a species of fish will certainly survive.

A legally established limiting value will go further than the economic optimum, as other values are also taken into consideration than those that can be expressed in terms of money.

<sup>a</sup> VROM (National Environmental Policy Plan) (1989) page 141

The limiting value can be established regionally; it can also be differentiated according to different functions (special environmental quality). Special environmental quality is the opposite of 'general environmental quality'. Based on separate general protection levels for drinking water, inland fisheries and shellfish, norms were established in, for instance, the Indicative Long-term Water Programme (IMP Water). Each of these protection levels is based on different criteria.

### Different supposed uses of damaged objects

The criterium for fishing water can thus be a dose-effect relation for a certain species of fish and a certain form of pollution. Also the consumability of the fish that will be caught can be used as a criterium for the quality of the water in which the fish will have to be caught. It is clear that the criterium for drinking water will be different again from that needed for fish.

### Levels of standards

Setting norms takes place on different managerial levels, beginning with the European level. The higher the managerial level and the larger the area over which the norm must apply, the more flexible the norm has to be to encompass all eventualities and to maintain a certain feasibility.<sup>363</sup>

### The length and frequency of exposure

The length and frequency of exposure are essential considerations when setting norms. Certain norms may be exceeded for a short while, but not too often. In addition, it can be established that excesses, if they take place at all, may not follow each other within a certain interval of time. Human beings or organisms need time to recover from a certain excess. From this it appears that, in many cases, setting norms demands a statistical approach. This approach, whereby norms can be given an average value, must not lead, though, to ignoring periods of peak stress. Exact values remain necessary, therefore, not only as a means of evaluation, but also especially because of their role as an indicator and as a maximum value for incidents ('98 percentile, and similar).

An example of these sorts of peak sensitive exposure norms are the so-called EPEL and MAC values<sup>a</sup>. The MAC values are hygienic values for companies, fixed by the national MAC commission under the terms of the Working Conditions Law (ARBO). The MAC values are the Dutch version of the American Threshold Limit Values (TLV).<sup>364</sup>

### Spatial zoning

The association of Dutch municipalities (Vereniging van Nederlandse Gemeenten VNG) made a list of approximately 700 businesses and 80 installations categories. For each category that list recommends to keep a distance in metres (zone) from quiet and mixed residential areas.

A downloadable Excel sheet offers that extended list in selectable parts<sup>b</sup>.

code	Distance to quiet residential areas	Distance to mixed areas (one category lower)
0,0	0	0
1,0	10	0
2,0	30	10
3,1	50	30
3,2	100	50
4,1	200	100
4,2	300	200
5,1	500	300
5,2	700	500
5,3	1000	700
6,0	1500	1000

Fig. 1027 Category codes of businesses and recommended distance to keep from residential areas<sup>c</sup>

<sup>a</sup> MAC means 'Maximaal Aanvaardbare Concentratie'

<sup>b</sup> environment.xls, downloadable from <http://team.bk.tudelft.nl/> > Publications 2008

<sup>c</sup> VNG, Vereniging van Nederlandse Gemeenten (2007) Bedrijven en milieuzonering. (Den Haag) SDU Uitgevers bv.

For different kinds of nuisance (**odor, dust, noise, danger, quiet areas, traffic, visual, soil, air**) different distances are given. The largest distance determines the category of nuisance (see *Fig. 1027*). Distance to mixed areas are one category lower than to quiet residential areas.

### From effect- into source-directed standards

The development of environmental quality requirements originates from the exposed objects (risk criteria, dose-effect relations). From this end effect, limits can be set on the indirect and direct effects of activities and on the activities themselves (see *Fig. 1012* and *Fig. 1013*).

Non-accepted exposure effects result in limiting values for the media air, water and the ground, from which environmental quality norms can be derived.

Emission limiting values and emission ceilings follow from this, as well as requirements and norms for products and processes towards which the activities lead.

The advantages and disadvantages of norms on the source and emission side compared with norms on the exposure and environmental quality side lie, on the one hand, in the area of the practical applicability of issuing licences and, on the other hand, in the possibility of objective under-pinning and the mutual consideration of different environmental stresses.

### Process and product standards

Applying quality and emission norms can, after all, in principle, prevent the sum of all sorts of different activities (e.g. industry, traffic and home heating, as sources of air pollution), even though reasonably clean in themselves, from causing, nevertheless, an unwanted or unacceptable situation. On the other hand, they do not help to grasp the specific possibilities that can exist in an individual pollution-reducing source. Process and product norms have the advantage that they tackle pollution at source. However, they make an approach based on regional conditions impossible. Emission norms and ceilings have a sort of intermediary position between both.

## 6.5.6 Environmental policy

### International principles: sustainable development and biodiversity

The 'Brundtland Committee' (World commission on environment and development, 1987) declared the principle of 'sustainable development' (to leave at least as many possibilities for future generations as your generation encountered). Since Agenda 21 (UN 1992), 'biodiversity' became an issue of these 'possibilities'.

### Core aim of the first National Environmental Policy Plan (NMP1)

The core aim of the first National Environmental Policy Plan (Ministry of Traffic, Spatial Planning and Environment (NMP) VROM (1989) was the *preservation* of environmental-usage space (milieugebruiksruimte) for the benefit of 'sustainable development'<sup>365</sup>.

So, the *production* of new environmental-usage space by building, the many possibilities of gain by urban and architectural design are thereby overlooked.

### Building, health and biodiversity

After all, the proper task of building is to increase the utility of the space for human beings and their future generations. Building is good for human health, because, without buildings there would be distinctly fewer survivors. In addition, buildings can increase the biodiversity of an area<sup>366</sup>. This means not only gains for human health, but also demonstrable gains in terms of biodiversity in the built-up environment.<sup>a 367</sup>

From the 500 wild plants that are found in Zoetermeer, *Fig. 768* shows, above the line, the species that already occur more frequently in urban areas than on average in the Netherlands. Thus one can conclude that building not only takes over existing environmental utility space, but also produces — and to a much greater extent — environmental utility space for human beings, plants and, in some cases, even for animals. If one doesn't include that environmental effect in the calculation, then the bookkeeping of the environmental utility space is incomplete.

<sup>a</sup> Jong, Tacke M. de (2003) *Milieuwinst en milieuverlies door bouwen*. In: Boersema, J.J.; Pulles, T.; Straaten, J. van der; Bertels, J. (2003) *De oogst van het milieu* (Amsterdam) Uitgeverij Boom [html](#)

### Urban and architectural contributions to environmental problems

However, in environmental policy the building industry is not appreciated for her environmental profits, but merely its negative impacts are taken into account (see Fig. 1028). In a supplement of the NMP (Ministry of VROM 1990) for the building industry, it has been established what 'contribution' this 'target group' (other target groups are: agriculture, traffic and transport, industry and consumers) makes to each field of problems (theme) within the estimated total for the Netherlands:<sup>368</sup>:

THEME	SPECIFICATION	CONTRIBUTION
Climatic change	air conditioning, isolation foam energy from fossil fuels for commuter traffic, the production of building materials, and heating	23% of the total CFC use > 33% of the total CO <sub>2</sub> production
Acidification over-manuring	commuter traffic, building materials, heating household waste water, emissions into the ground and into groundwater	>16% of the total NO <sub>x</sub> and SO <sub>x</sub> production 24% of the total nitrogen and phosphorus production
Dispersing environmentally damaging substances	solvents, preservation, upkeep, asbestos, heavy metal emissions when insufficiently re-cycled	9% of the volatile organic substances, 40,000 tons of heavy metals, 7,000 tons of pigments
Removal of waste materials Disturbance	building and demolition waste noise and foul smells due to traffic, building, production and quarrying building materials	20% of the total waste 2.85 million homes suffering from (serious) disruption due to traffic, 25% of the population in small towns irritated by foul smells
Wastage	careless use, not much re-cycling	120 million tons of raw materials per year, 90% of which are primary raw materials
Internal environment	health effects due to building materials, moisture, quality of the internal air, sound, vibrations	number of homes above the reference value: 90% NO <sub>x</sub> , 80% radon, 80% airborne sound insulation, 60 % respirable substances, 15% moisture problems, 6% carbon monoxide, 40% of the offices are 'sick' buildings
Damage to ecologically functioning area	building surface with isolated ground ecology, quarrying for building materials	3,100 km <sup>2</sup> of hardened surface, 1,000 ha/year open-cast mining, of which 500 ha of definitive changes in destination

Fig. 1028 The contribution of the building industry to environmental problems in the '90s

The building industry was able to bring about reductions of spare parts of more than 20%, for example, by not applying foam containing CFKs to insulation material or by not basing air conditioning on these compounds, or by rendering them totally redundant. This applies to more of the contributions named in this table.

In 'Environmentally considered building' started by the Ministry of Traffic, Spatial Planning and Environment (VROM), discussions took place with the industrial branch as to which reductions in the different types of environmental pressures could be achieved in the long term (target values) and various shorter term limiting values that had to be met before a certain year.

### Environmental problems and targets

The NMP1 distinguished environmental problems according to the level of scale they can be solved (not according to their effect, which is always local):

- Global problems: ozone layer and climate change<sup>369</sup>;
- Continental problems: border crossing air pollution, ozone on living level, acidification, smog, heavy metals<sup>370</sup>;
- Fluvial problems: rivers, regional waters, salty waters, water bottoms<sup>371</sup>;
- Regional problems: accumulation of pollution, over-manuring, pesticides, heavy metals, removing waste, soil pollution, drying up<sup>372</sup>;
- Local problems: noise pollution, smell pollution, urban air pollution, inside environment<sup>373</sup>.

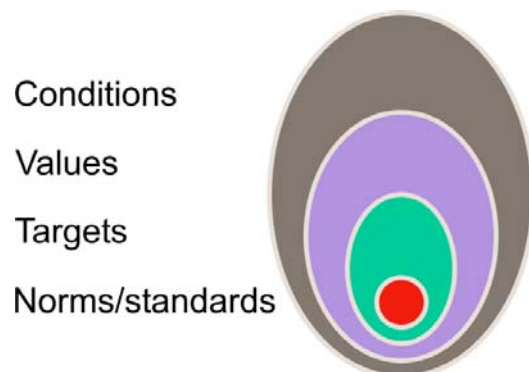


Fig. 1029 Conditional suppositions of norms/standards

According to these levels, targets were elaborated into standards according to limit values (see Fig. 1029) in cooperation with international, national, provincial and local authorities.

**From an effect-oriented into a source-directed policy**

The NMP1 marked a change into source-directed policy by making separate appointments with target groups like:

- agriculture;
- industry;
- refineries;
- energy supply companies;
- building companies;
- trade, services and governmental institutions;
- traffic;
- consumers;
- waste processing companies;
- participants in the water chain;

However, effect oriented measures remained actual for:

- problems herited from the past;
- source-directed measurements not coming in time;
- preventing calamities;
- failing source-directed measures.

The source-directed measures were distinguished into:

- emission directed;
- volume directed;
- structural measurements like integral chain management, energy saving and quality improvement.

These measures were discussed with the target groups (see Fig. 1030).

**An agenda to discuss with target groups**

The NMP used the following policy outlines as an agenda to the discussions with target groups:

<i>effect oriented</i> (main emphasis of the '70s: ground, water, air)	
<i>source oriented</i> (the '80s)	<i>emission oriented</i> (removal at source)
	<i>volume oriented</i> (less consumption and production)
	structural
	<i>energy saving</i> (energy)
	<i>integral chain management</i> (material)
	<i>quality improvement</i> (information)

Fig. 1030 *Outlines of environmental policy*

In these 'policy outlines', environmental care is recognisable within effect, emission and volume oriented policy. It is only when it comes to 'structural' policy that innovational environmental techniques are dealt with.<sup>374</sup>



## Strategic agenda

The government itself handled a strategic agenda of:

- reducing uncertainties;
- making choices from scenarios;
- formulating themes, instruments and cooperation.

These themes, instruments and cooperation are elaborated below.

## Environmental themes supposing each other

Since the first National Environmental Policy Plan environmental themes have been: wasting, removing, disturbing, drying up, spreading, acidifying, over-manuring (the 'VER-thema's' in Dutch)<sup>375</sup>.

However, a conditional analysis of these (VER-) themes " (zie Fig. 1031)<sup>376</sup> shows they overlap. For example wastage has been tacitly presupposed as an environmental problem in all of them. If wastage is the main problem, then sunlight, rain, and leaf-fall in the autumn should also be avoided. The theme words are interpreted here according to their meaning in everyday language<sup>377</sup>.

In a professional sense, a clarification of that is presupposed, but is sometimes forgotten. What is meant by 'dispersion' is the dispersion of environmentally toxic substances, excluding CO<sub>2</sub> (climate).

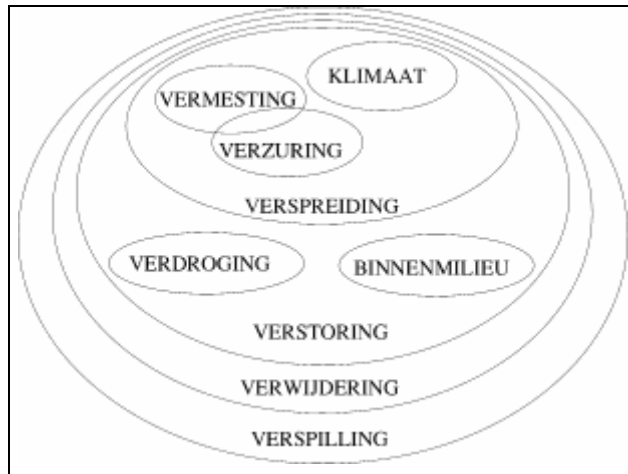


Fig. 1031 *Environmental themes from the NMP, shown according to their conditionality*

The tacit presupposition is thus: 'in so far as it is not connected with the dispersion of acidifying or manuring substances, or CO<sub>2</sub>.

However, in everyday language, one cannot imagine climate problems, acidification and over-manuring without the dispersion of substances responsible for this. Ecologically, this dispersion is irrelevant, in so far (again, according to everyday language) as it causes no disturbances. However, 'disturbance', in professional language refers mainly to disturbance of the living environment due to noise, foul smells, insecurity, and is thus, in contrast to climatic problems, very local. The tacit presupposition is then: disturbance in so far as it is not connected with drying up, interior environmental problems and dispersion.

## Double counting

The government preferred to convert environmental effects into these themes. That means that, in effect analysis, there is a danger of double counting, due to environmental values that presuppose each other. In methods such as LifeCycleAssessment, an attempt is made to add up the effects by theme, but if a certain environmental pressure has more than one effect, it is unjustifiable to include that pressure several times in the calculation.

## Calculations by RIVM

That is why for each theme, the environmental planning bureau RIVM yearly checking governmental policy results, repeatedly asked itself the same question: 'and why is that bad?'. The conclusion remained unchanged, that it is hardly possible in the Netherlands to determine the effects on health, but that, for each theme, 'a possible loss of biotopes' should be regretted.

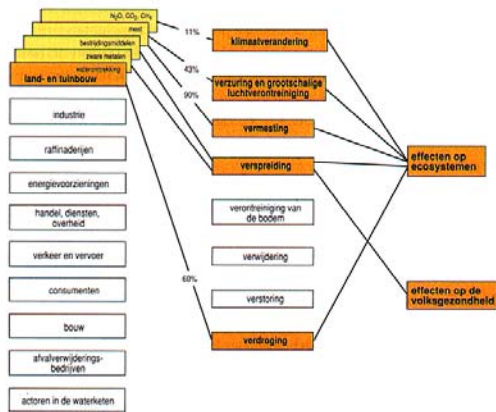


Fig. 1032 Calculating impacts of target group 'agriculture' on every theme, reduced to impacts on biodiversity and health

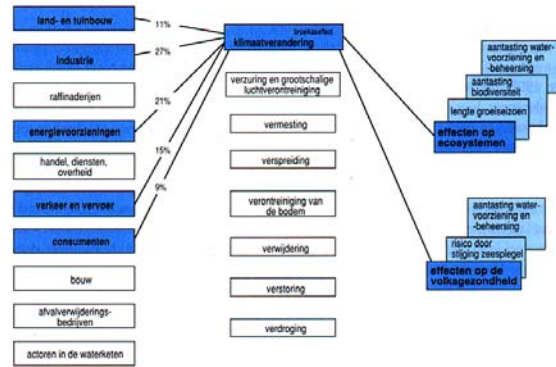


Fig. 1033 Calculating themes from contribution of every target group, reduced to impacts on biodiversity and health

### Instruments and cooperation

NMP1 distinguished the following instruments:

- regulations by law;
- liability;
- financial regulations;
- environmental care in companies;
- product norms;
- information and public relations;
- technology;
- energy saving.

in cooperation with: international, national, provincial and municipal institutions.

## National policy documents after NMP1



Fig. 1034 *Four national plans concerning the environment*

There are four more recent national policy documents with environmental criteria for plans on different levels of scale from the Ministries VROM<sup>a</sup>, LNV<sup>b</sup> and V&W<sup>c</sup>:

- The 5<sup>th</sup> National Plan of Spatial Policy NRO5, VROM (2000),
- The National Plan of Nature Policy LNV (2000),
- The 4<sup>th</sup> National Plan of Environmental Policy NMP5, VROM (2001),
- The 4<sup>th</sup> National Plan of Watermanagement Policy V&W (1998) (stressing environment), and
- its successor 'Anders omgaan met water' V&W (2000) (stressing security).

Some of these policies are elaborated in a regional policy. The RIVM<sup>d</sup> is supposed to test plans on the subjects of health, environment and nature. Some of the produced criteria are summarised below.

## European policy

P.M.

<sup>a</sup> <http://www.minvrom.nl/minvrom/pagina.html>

<sup>b</sup> <http://www.minlnv.nl/>

<sup>c</sup> <http://www.minvenw.nl/cend/dco/home/data/index.htm>

<sup>d</sup> See <http://www.rivm.nl/>

## 6.6 Soil pollution

### Choice of location

The choice of location for a building, complex or new neighbourhood depends on position, orientation, land shortage and potential soil pollution, and as such comes with a price tag attached. Readers are not expected to “know” the contents of this chapter. Those factors that play a part in the choice of location are marked with a question.

As well as determining the choice of location, this topic is also of interest to urban planners and architects. After all, most contracts depend on the commencement date of building activities, allowing sufficient time to obtain the relevant permits and to plan activities. A lack of knowledge concerning soil pollution – including the relevant permits – will delay activities.

### Soil protection act

This chapter offers guidelines for carrying out research in the context of the decontamination clauses of the Wet Bodembescherming (Soil Protection Act), with the emphasis placed on “terrestrial soils”. Detailed information will be given on a range of pedologic properties and concepts. Examples of potential areas affected by soil pollution are also included, as is a brief summary of remediation techniques.

### Surveys to obtain a clean soil statement

This monograph, coupled with a concluding report, will enable building contractors to carry out exploratory and preliminary surveys into soil pollution to initially obtain a “clean soil statement”.

### Clean soil statement depending on purpose

Until comparatively recently, planning permission applications needed to include a so-called “clean soil statement”. This has been replaced by a suitability certificate, indicating intended purpose. As a result, the soil no longer needs to be completely “clean”, provided it is deemed suitable for its designated use. Building work cannot commence until this declaration has been issued. This certificate is not only concerned with the topic of soil pollution, but also with “cleaning”, soil remediation, if pollution has been detected.

### Protocols and methods

To encourage greater understanding of the underlying problems, this thesis shall focus on the protocols involved in the investigation procedure into (likely) contamination (and resulting reports), and highlight a number of pedologic concepts.

This chapter is concerned with outlining the different types of contamination, coupled to industry activities, their prevention and location in the townscape and landscape. Current and developed remediation methods have been included for the sake of completeness. The underlying idea is that decontaminating and preparing a terrain for development follow naturally from one another, or could even be carried out in unison, thereby influencing the overall design.

## 6.6.1 Soil pollution

### Suitability for future purposes

The term ‘soil pollution’ denotes a negative impact on soil quality, which affects the soil to such an extent, that it is rendered unsuitable or less suitable for its intended purpose.

The soil must be protected in such a way, that future generations can make use of it. This means that the soil must not be damaged, or become irrevocably damaged, in accordance with the concept of sustainability.

### Different types of damage

When analysing our exposure to substances in the soil, we can identify different types of damage/exposure. In the case of soil pollution, this exposure includes inhaling VOCs (volatile organic compounds), consuming soil particles when drinking water, etc.

The situation is exacerbated by the consumption of dangerous substances that put our health at risk. The level of exposure is expressed in ADI (acceptable daily intake). Please note that ADI differs from person to person. As such, an average figure applies.

## Functions of soil

With regard to soil pollution, it is advisable to consider the different functions of the soil, and the relevant quality assessments to be adopted.

- supportive function for buildings, roads and other constructions
- productive function: growth medium for natural vegetation and agricultural crops to feed people and animals.
- filter function for water
- ecosystem function; life in the soil makes a major contribution to the cycle of C, N and S.

To acquire a better understanding of these functions<sup>a</sup>, it is essential that we have a general understanding of the concept of soil.

## 6.6.2 General soil knowledge

### Soil and ground

What is the difference between soil and ground?

- The term 'ground' refers to all the loose natural materials found at the earth's surface. In terms of composition, it is an undefined material. The material consists of mineral matter and organic components that can be retraced to plant remains and conversion.
- The term 'soil' refers to the arrangement of the individual soil particles, their size and how they occur in nature. Chemical, physical and biogenic processes play an important part in soil formation.

### A closer definition

The Dutch language fails to differentiate the terms 'soil' and 'ground'. This problem can be solved by including a definition.

Soil and ground are made up of solid, liquid and gassy constituents. Solid constituents are divided into mineral and organic constituents.

The naming of ground types is based on particle-size distribution of the mineral particles. Please note that most grounds do not have a homogenous particle size. In other words: the designation 'sandy ground' implies that the majority of particles fall under the particle size fraction of sand.

### Particle size

We can distinguish the following particle size fractions:

- to 2 $\mu$ : clay fraction or clay
- 2 $\mu$  to 50 $\mu$ : silt or loam
- 50 $\mu$  to 2000 $\mu$ : sand (2000 $\mu$ = 2 mm)
- 2 mm to 64 mm: gravel

### Organic matter

The organic matter in ground is made up of decomposed plant remains. If these remains form a thin layer on the soil surface, we refer to them as humus, which is brown-black in colour. Thicker layers of organic material (up to several metres thick) are known as peat. Due to excess water, the plant material has not been converted into humus. Peat is primarily converted into humus following drainage of moist peatland, in particular under influence of oxygen.

### Groundwater

Water contained in the ground can take on different forms. A distinction is made between

<sup>a</sup> Dauvellier and v.d. Maarel, Globaal ecologische model, Rijksplanologische Dienst 1978

- groundwater: this water fills all pores between the particles, both big and small, and flows freely.
- The upper limit of the groundwater is known as the ground-water table or phreatic level.
- The depth (or height) of the ground water is always measured in relation to the ground level
- capillary water: this water saturates the fine pores and fissures of the ground, and is unable to move freely.
- swell water and adhesion water: water in and around the solid soil particles.
- Capillary water, swell water and adhesion water are also known as soil water.

**The colour of drilled water**

The groundwater level of a terrain can easily be established through soil drilling. In the Netherlands, the ground beneath the ground-water table – fully saturated by water – is grey in colour due to iron having the bivalent oxide FeO. Above the phreatic level, iron only occurs as Fe<sub>2</sub>O<sub>3</sub>, which is rusty in colour. This method is not 100% foolproof however, as numerous grounds in the Netherlands contain little or no iron.

**Groundwater tables**

Groundwater tables are divided into water-table classes, where the highest mean groundwater level (HMGL) and lowest mean groundwater level (LMGL) groundwater level is processed. The groundwater level is determined in relation to the ground level; the depth of the groundwater is representative.<sup>378</sup> The annual natural fluctuation of the groundwater in the Netherlands amounts to several centimetres (10 or more). This movement is characterised by rust stains in the grey-blue groundmass.

Gt	I	II	III	IV	V	VI	VII
GHG	-	-	<40	>40	<40	40-80	>80
GLG	<50	50-80	80-120	80-120	>120	>120	>120

N.B. groundwater level in cm's below ground level.

Fig. 1035 Main subdivision of the water-table classes

**Groundwater flows**

Downward groundwater flows are the result of differences in groundwater levels in an area. Although the general direction of the groundwater flow is known, it will need to be determined for local situations.

In addition to horizontal groundwater flow, we can also identify a vertical movement of water in the ground. This is known as effluent seepage (kwel), where the water 'surfaces' from the ground-water, and infiltration, characterised by 'downward movement' of water.

Soil pollution can spread through the soil through groundwater flow. An insight into the degree, velocity and direction of spread is therefore essential.

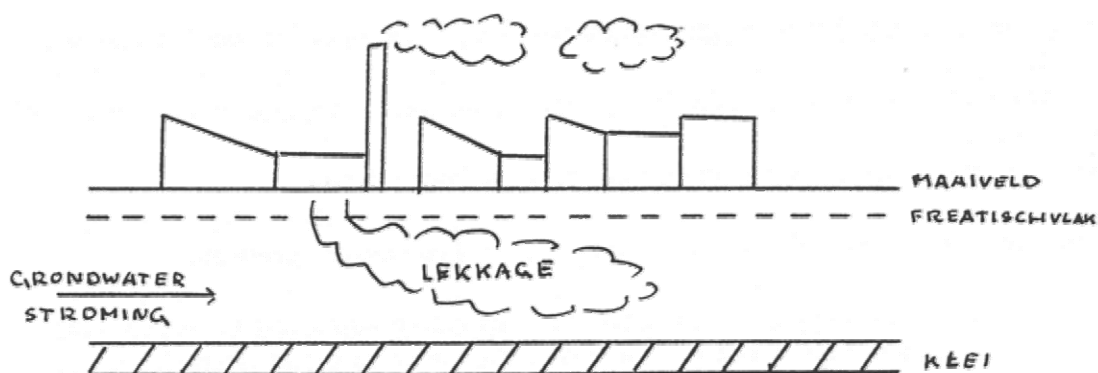


Fig. 1036 Horizontal groundwater flow



### Soil vapour

Soil vapour occurs in all areas where the pores of the soil are not saturated by water. This air plays a part in all biogenic activities in the ground, but can also be relevant for the different chemical processes in the soil.

The composition of this soil vapour can vary strongly. The air is usually more or less identical to the atmosphere. However, because of the chemical pedological processes and soil pollution, the composition can differ significantly from the atmosphere, and even be toxic.

### Ground types

On the basis of the solid constituents of the ground, it can be classified into sand, clay and peat.

- sandy ground; this ground primarily consists of mineral soil particles with a particle size of 50 to 2000  $\mu$ , while the clay content (particles) is less than 8% of the overall weight per unit of ground; ground permeability is good
- clay; this ground contains at least 25% clay fraction; ground with a clay content of 8-25% is known as sandy clay; ground permeability is poor or non-existent.
- peat ground; this ground is primarily made up of decomposed plant remains other than humus. The organic dust content must be at least 22.5% of the weight. The other constituents are mineral and can contain particle sizes of clay and sand.

## 6.6.3 Soil pollution and building activities

### Application (previous) "clean soil statement"

Until comparatively recently, planning permission applications needed to include a so-called "clean soil statement". This has been replaced by a suitability certificate, indicating intended purpose. A soil survey report needs to be submitted during the application stage. The investigation must be carried out in accordance with the "Soil Protection Guidelines". If the exploratory survey (historic survey) reveals signs of soil pollution, a follow-up investigation will be required.

### Historic survey

When drawing up his historic survey report, the investigator makes use of standardised survey setups, as well as municipal information and assessments. In many cases, the relevant council can provide information on behalf of the "historic survey". Based on the outcome of the survey, an exploratory investigation is instigated if serious contamination is suspected. The sole purpose of this investigation is to indicate the incidence of serious soil pollution.

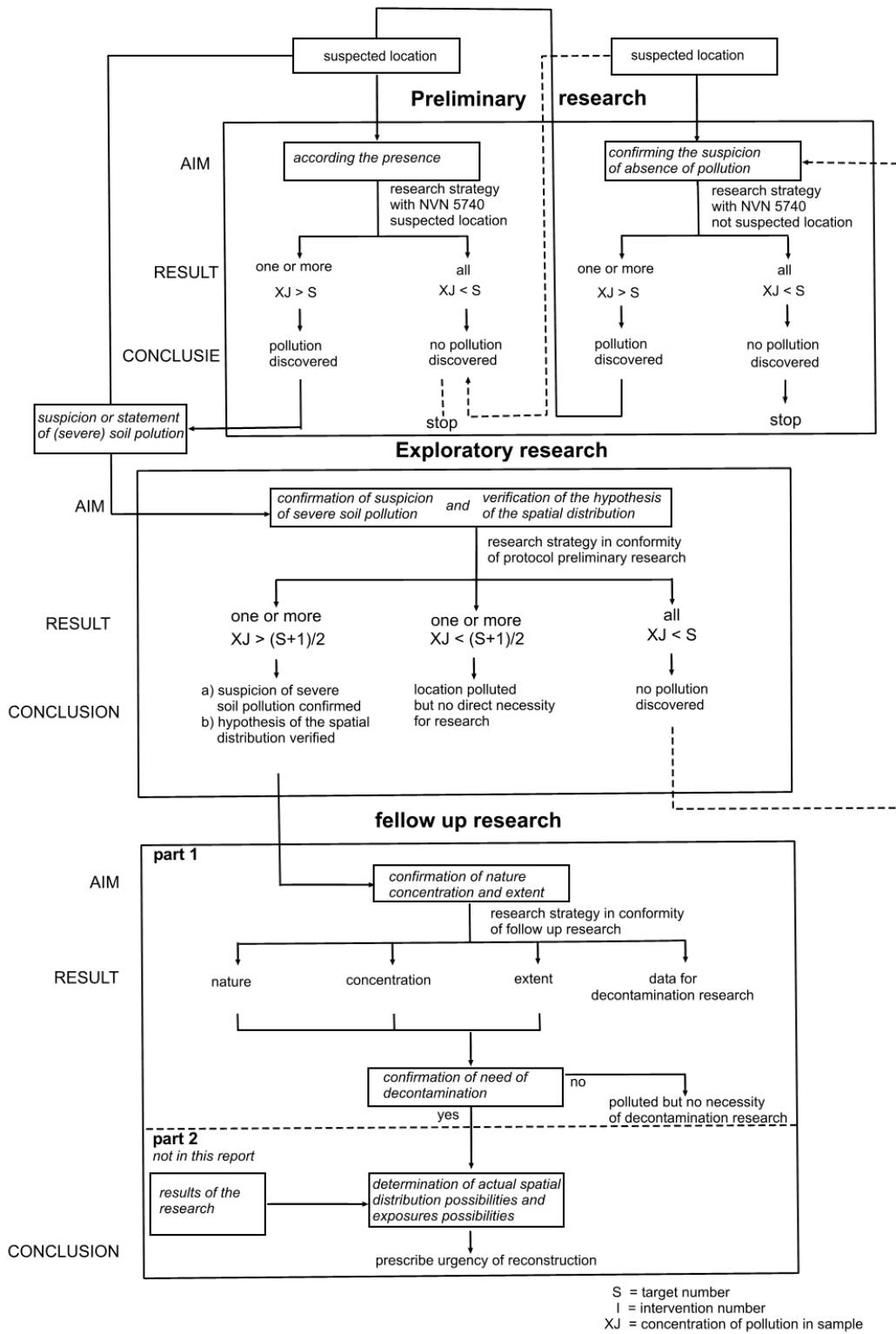
### Setup and criteria

The setup and criteria which the investigation must satisfy are laid down in two protocols:

- "Protocol voor het oriënterend onderzoek" (naar de aard en concentratie van verontreinigende stoffen en de plaats van voorkomen van bodemverontreiniging) ("Exploratory survey protocol" (into the nature and concentration of contaminating substances, and the location of soil pollution) SDU, The Hague 1993).
- "Protocol voor het nader onderzoek" (naar de aard en de concentratie van verontreinigende stoffen en de omvang van bodemverontreiniging) deel 1, SDU,'s Gravenhage 1993.
- ("Follow-up investigation protocol" (into the nature and concentration of contaminating substances, and the scope of soil pollution) part 1, SDU, The Hague 1993).

On the basis of both protocols, an overview is included of the survey methods to be deployed, including information relevant for building contractors. If you wish to carry out this survey yourself, you will be required to comply with these protocols.

*Relationship between different research strategies*

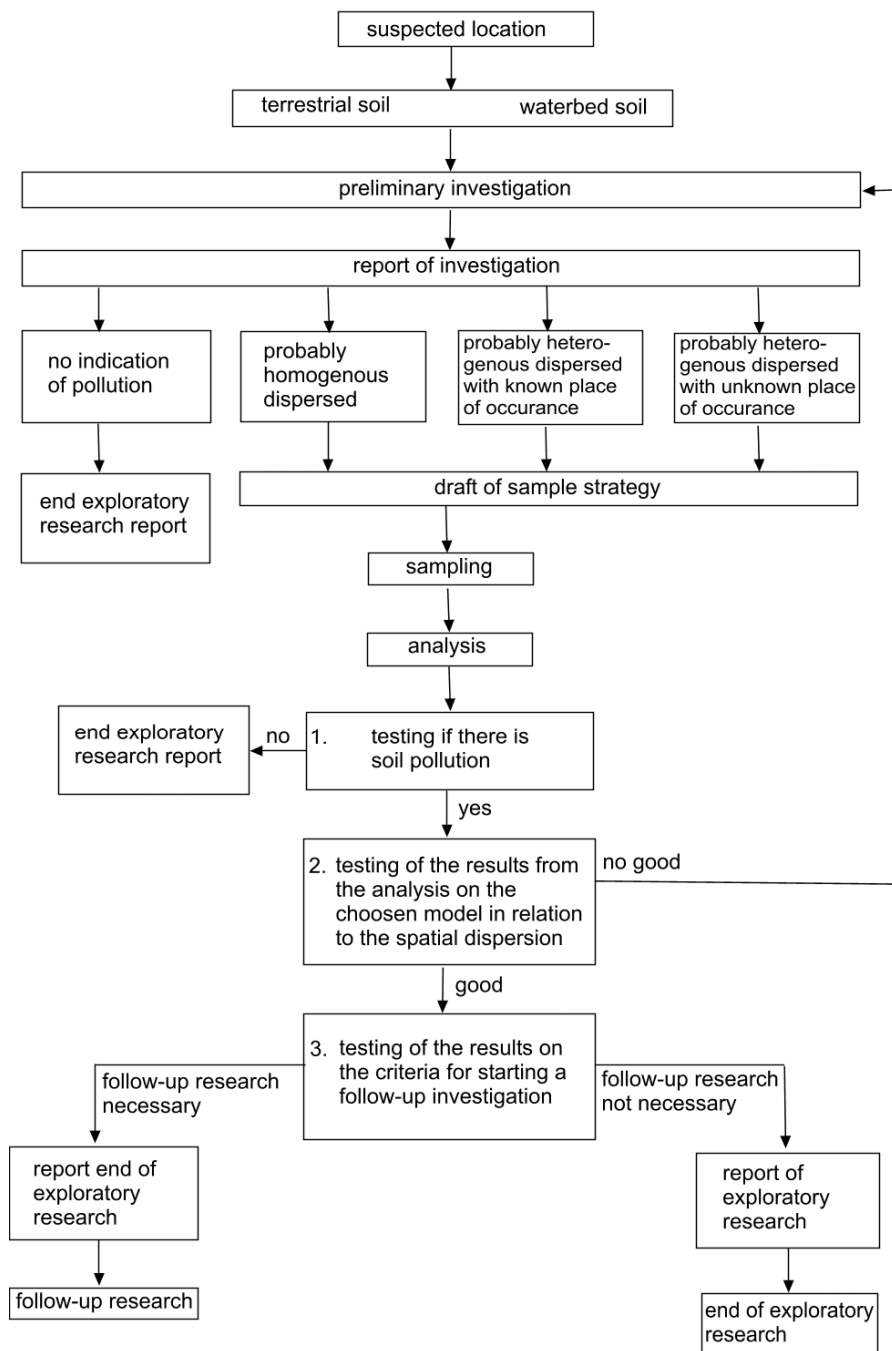


The exploratory research in conformity of NVN 5740 refer only to the research of a land soil.

*Fig. 1037 Research strategies in protocols<sup>a</sup>*

<sup>a</sup> F.P.J. Lame and R. Bosman (1994)

### 6.6.4 Exploratory survey



The structure of the exploratory research is the same for terrestrial soils as for waterbed soils; the strategy for sampling can differ on certain parts.. The soehme should be executed seperately for both soil's.

F.P.J. Lame and R. Bosman (1993)

Fig. 1038 Exploratory survey protocol<sup>a</sup>

<sup>a</sup> Lamé and Bosman, Protocol voor het oriënterend onderzoek, SDU, Den Haag 1994

## Terrestrial soils and waterbed soils

As demonstrated by the above diagram, the exploratory survey is divided into terrestrial soils and waterbed soils, while the survey itself is divided into an exploratory investigation with a concluding report, and a more detailed investigation in the event of soil pollution. This investigation is also concluded with a report.

## Exploratory survey

An exploratory survey must be carried out at all times to obtain a suitability certificate to commence building work. This process involves collecting information and data on past and present use of the site, as well as the soil conditions, soil composition and the (geo)hydrologic setting. This might also involve the pollution crossing terrain boundaries, from the location "outwards", and "outwards" towards the location. Pollution might also concern the ground beneath the buildings, in particular if we are dealing with a permeable soil such as sandy ground.

The investigation includes an on-site visit. During this visit, soil drillings can be carried out to gain an impression of the soil composition and the likely contamination detected through sensory perceptions (colour and odour).

Please take your own safety into consideration; be careful when inhaling and touching substances. If you need to smell and/or touch something, please do so in small quantities at a time.

## Terrestrial soils

The sampling strategy of the follow-up investigation is based on information obtained from this "field visit" – such as location and structural condition of the buildings.

With regard to construction work, we will confine our research to terrestrial soils. In cases of contaminated subaqueous soils, readers are referred to the research methods detailed in the above literature.

## Information required for exploratory survey

As previously mentioned, this information needs to include details on:

- past and present use of the site
- the soil composition and geo-hydrologic settings of the site.

As a minimum, information on past and present use of the site must contain the following details:

- past purpose(s) of the location and immediate surroundings;
- location of occurrence of possible sources; for example legal or illegal dumping and discharging, leaking (underground) pipes and tanks. Council registrations of pipes and storage tanks are a useful tool in detecting the source of contamination.
- information on potentially contaminating activities, such as production processes, storage and transfer locations. Remember also to draw up an inventory of the relevant substances. An indication of the location of these activities, if possible, will simplify inventory activities and the investigation.
- methods and materials used in the past for preparing a site for building, including opening up the site.
- details of in-situ cables, pipes, debris, consolidations.
- past and present activities on adjoining terrains.
- investigations into soil pollution on neighbouring or adjacent terrains
- inventory of past users of the terrain, with their activities from approx. 1900.

### **Information on soil composition and geo-hydrologic settings of the site**

As a minimum, this information must encompass the following:

- on-site soil composition, both shallow and deep (over 10m); information obtained from soil drilling tests and drilling;
- depth of the ground water
- horizontal and vertical movements of the ground water (effluent seepage, seepage and groundwater flows)
- position of water channels and other surface water (also drained)
- presence of groundwater sources and groundwater drawoff
- prevention of brackish and/or salty ground water
- results of earlier soil surveys on-site or in the immediate surroundings; also include past surveys into soil pollution.

### **Adding contaminating substances and microbiological activities**

It is advisable to incorporate into the survey research into the properties of contaminating substances and microbiological activities. Although it is not compulsory to include this information, it can provide a valuable insight into the problems, and assist in selecting an investigation strategy and, if need be, determining the remediation method.

### **Past and present use**

The information on past and present use of the site, as well as the information on soil composition and geo-hydrologic settings of the site, needs to be incorporated into the exploratory survey report, including relevant sources.

### **How to obtain information for an exploratory survey**

How can we obtain the relevant information?

- use recent maps: topographical, from the land registry and maps of pipelines and mains, as well as soil and geological maps including legends. The local council office can usually provide historic data.
- use of old and recent aerial photographs, which can be obtained from the municipal topographic service and numerous aerial photography firms. Additional tools include infrared and other recordings falling under the heading of 'remote sensing images'.
- exploratory visit to the site, carrying out field observations and soil drillings to take samples.
- investigation into archives, permits and dossiers (under the Nuisance Act) relating to past and present use of the terrain
- interviews with (former) employees and the local community
- use of archives of different municipal, provincial and government institutes
- branch-information concerning past use of the terrain in relation to possible contamination
- historical information from council and water boards.

This information must be incorporated in the report, concluding the exploratory survey.

### **Provisional conclusion**

If all (writing desk) investigations indicate the likelihood of soil pollution, the survey must be extended to include information on the nature and concentration of the contamination collected on-site and laboratory analyses. This effectively is the start of the exploratory survey; a certain degree of in-depth research is required. A section of the preceding research must be expanded and deepened, as the results of the exploratory survey indicate a suspected case of soil pollution and a rough understanding of the contaminating substances. The distribution of these substances has also been mapped out in outline. On the basis of this information, a strategy is developed for the research methodology in general, and samples taken. The selected method(s) are subjected to tests, essential for eliminating potential mistakes and focussing the investigation, if need be.

This survey reveals whether we are actually dealing with soil pollution, and is concluded with a report, indicating the presence of soil pollution and recommendations for "further research".

### **Additional notes concerning the exploratory survey**

In the event of a contaminated land soil, it is not necessary to examine the groundwater, provided the mobility of the contaminating substances is negligible. It would however be wise to do so, as most contaminating substances are either soluble in water or present in liquid form in the ground.

Sensory perceptions of contamination – by smell and/or perception or the identification of something "different" in the ground - is not really objective, but rather indicative. In addition, complicating factors must be taken into consideration, such as potential health risks for the observer. Visual perceptions can also be clouded by the natural colour of the soil.

With regard to safety, VROM (Environment Ministry) has produced a series of publications. When carrying out a soil sample, a certain degree of care must be taken, not only by those taking the sample, but also by onlookers. As a minimum, warning signs must be displayed in the event of assumed contamination. Even better would be to temporarily close off the site.

### **Sampling strategy**

In principle, there are different contamination types and therefore different sampling strategies. Homogeneously spread contamination requires evenly distributed sampling. This is based on 1000 m<sup>2</sup> spatial units (RE) in the horizontal plane. Per RE, 3 drills must be carried out, whereby the resultant ground samples are put into a mixed sample of the suspect layer and analysed.

An alternative sampling method is used for heterogeneously distributed contamination in known and unknown place of occurrence. As the preceding investigation has determined the type of contamination and its spread, a specific sampling method can be drawn up.

Needless to say, research results will need to be tested.

The exploratory survey is concluded with a report. In the event of actual soil pollution, a follow-up investigation will be carried out in accordance with the applicable norms.

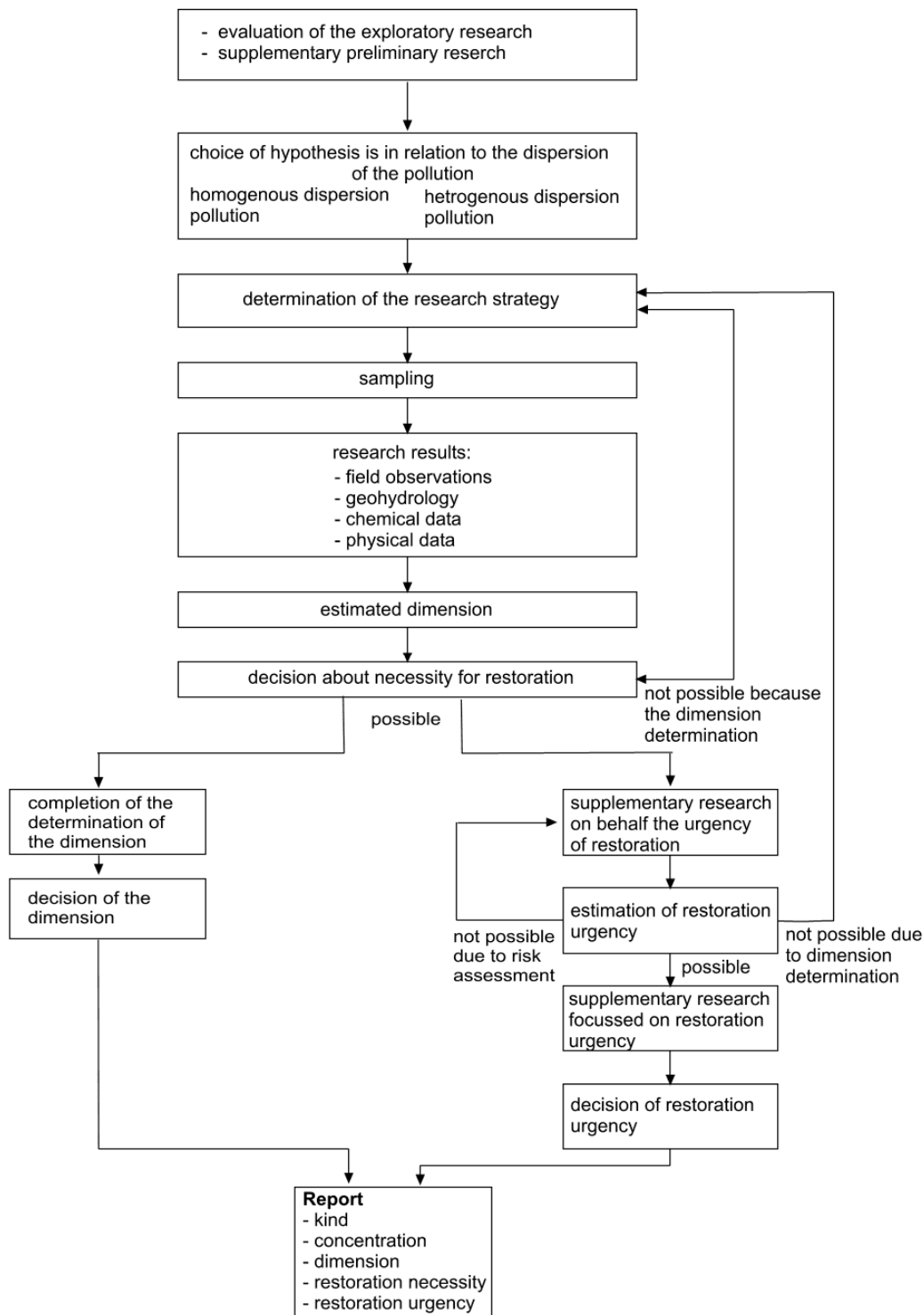
### **Carrying out the investigation**

In principle, anyone can carry out the survey, provided the details on past and present use have been incorporated in the final report. The same applies to information on soil composition and the geohydrolic setting. Soil samples that require analysis can be carried out in a specialist soil analysis laboratory on the instructions of the researcher.

The exploratory survey can also be entirely outsourced to a specialist research agency.



## 6.6.5 Follow-up investigation



F.P.J. Lamé and R. Bosman (1993)

Fig. 1039 Protocol for follow-up investigation<sup>a</sup>

### The follow-up of an exploratory survey

Having completed the assessment of the exploratory survey, plans are now drawn up for a follow-up investigation (including additions to the exploratory survey).

<sup>a</sup> Lamé en Bosman, Protocol voor het nader onderzoek, SDU, Den Haag 1994

The aim of this investigation is to establish the nature and concentration of the contaminating substance(s) in both the horizontal and vertical plane.

An insight into the local soil composition is essential, as is soil sampling. Regulations have been drawn up for this purpose. Soil sample analyses and results interpretations must be carried out in accordance with the protocol.

A follow-up report is drawn up on the basis of the results.

### **The contents of a follow-up investigation**

This report must comprise the following information<sup>379</sup>:

- nature of the pollution
- concentration of the pollution
- extent of the pollution
- need for remediation
- urgency of remediation

N.B. this report does not offer advice on whether remediation is required, nor on the remediation method. These decisions are taken by the relevant institutions.

### **Implementation of the investigation**

In principle, anyone can carry out this follow-up investigation. However, due to the substantially more complex nature of this investigation – in particular with regard to the behaviour of substances and pedologic research, it would be advisable to enlist expert help.

### **Determining the level of urgency for soil remediation**

A systematic approach has been drawn up to determine the level of urgency for carrying out soil remediation work. This approach is partially based on the existence of unacceptable risks in the event of serious soil pollution. The eventual decision to carry out remediation work is taken by the competent authority.

This problem falls outside the scope of this dissertation.

Further information is contained in the Urgentie van bodemsanering (urgency of soil remediation), published by the SDU.

## **6.6.6 Causes of soil pollution**

### **Industrial sites**

In view of the fact that most incidences of soil pollution are likely to occur in industrial sites, we have confined our research to these areas. It must however be noted, that these terrains are also found in built-up areas, and that a petrol station and garage in a residential area may also be a potential contributor to soil pollution.

### **Causes**

In general, the causes of pollution on industrial sites include<sup>380</sup>:

- leaking (underground) storage tanks and company sewers. These types of leaks are frequent occurrences, spanning longer periods. In addition, the replenishment of tanks can cause numerous problems.
- Old storage tanks for central heating oil are often located in the vicinity of residential buildings
- discharges directly into the ground of the industrial site
- dumping company waste on own site
- land fills containing own company waste and/or waste matter such as ash, waste products and cinders from incinerators.
- calamities such as fire, explosions, floods, pipe fractures etc.

### **Ignorance, mistakes, leakages and accidents**

Many contaminating substances have entered the ground in the course of time due to ignorance, mistakes, leakages and accidents such as spillages when transferring material or fuel.

The absence of clear operational regulations governing the handling of raw materials and the end product with regard to storage, transfer and carriage, as well as the disposal of waste matter, have almost certainly contributed to soil pollution.

The often lackadaisical attitude of managers and operational staff is a further culprit.

### **Terrains other than industrial sites**

In addition to industrial sites, soil pollution regularly occurs in waste dumps (rubbish tips), storage yards of (polluted?) ground, mines, quarries, gas and oil rigs and salt extraction areas etc. Pollution may also be generated by the re-use of, for example, previously contaminated building materials, as concrete aggregate. In Rotterdam for example, contaminated debris of WW2 aerial bombardments is still causing significant problems. Agriculture and horticulture are also potential polluters due to their use of pesticides and fertilizers.

### **Standardisation of A, B and C values**

The standards governing the most frequently occurring forms of soil pollution are drawn up in a "test table" for ground and groundwater in the Leidraad Bodemsanering (Soil Clean-up Guidelines). These standards are subject to alterations, and can be amended in line with recent surveys. As such, it is essential that the most recent tables be used. It seems best therefore to use the term "indicative target values", which are divided into A, B and C values.

- The A value is the reference value. If this value is exceeded, we are dealing with contamination<sup>381</sup>. The A value differs per soil types, as adsorption processes are particularly relevant in clay and peat grounds. In other words: if this (contaminated) ground has an A value, it is suitable for all purposes.
- The B value is an indicator of contaminated soil; it does not reveal to what extent the soil is contaminated. Further research is required in accordance with the "exploratory survey" protocol.
- The C value is the actual test value. In this case, soil remediation is required in accordance with the "follow-up investigation" protocol.

The system of A, B and C values was replaced in 1995 by a system of clean soil target values<sup>382</sup> (new A value) and soil remediation intervention values<sup>383</sup> (C value). The intervention values are based on risk assessments, highlighting risks to the eco system as well as risks to man.

### **Relationship industrial sector and soil pollution**

Industrial sites are categorised as follows in soil pollution surveys:

- former gas factories
- former and existing industrial sites
- former and existing car and machine wreck depots
- former and existing tips in general
- former and existing goods transshipment sheds
- former and existing borrow areas (coals, oil, salt, gas, clay, rocks etc.)

### **Costs**

In 1991, soil remediation costs amounted to approximately 84 billion Dutch Guilders, and primarily concerned remediation of former industrial sites.

### **Company operations**

The relationship between soil pollution and industrial sector is self-evident. The risk of soil pollution is effectively dependent on company operations<sup>a 384</sup>.

<sup>a</sup> De tabel is ontleend aan het boek "Bodemsanering van bedrijfsterreinen", praktijkboek voor bedrijf en beroep van Ing.J.Verschuren (ISBN 90-9003485-4) geeft enig inzicht in deze relatie.

<b>Business operation</b>	<b>Pollution</b>
metal and galvanic industry	all kind of heavy metals, cyanids aromates and chlorinated solvents (Tri and Per)
paint and dye industry	all kind of heavy metals, PCB's, aromates and chlorinated solvents (Tri and Per)
graphic industry	idem
textile industry	chlorinated solvents (Tri and Per)
chemical lavendaries and textile cleaning service	all kind of heavy metals, pak's and chlorophenol
carpentry and wood preserizing	
tanning and leather working industry	hydrocarbons and chromium
petrol stations	mineral oils, aromatics and lead
garages	mineral oils, aromatics, lead and battery acid
breaker's yard	all kind of heavy metals
pesticide industry	halogenated, hydrocarbons, aromatics, mercury, tin and arsenicum.

*Fig. 1040 Overview of prominent forms of soil pollution per operation<sup>a</sup>*

### **Pollution types and occurrence in the soil**

Soil pollution can take on different forms, depending on chemical composition, phase (gas, liquid, solid) and ground type. Clay ground particles for example can be contaminated through adsorption, immobilising the particles. The intervention values (previously B and C values) differ for clay grounds and sand grounds. Sand ground is unable to form a compound with contamination particles.

### **Types of form**

Incidences of pollution:

- solid form – solid particles: metals, compounds of heavy metals and metalloids
- adsorption - cation: adsorption of soluble salts of heavy metals to clay particles and organic components of the ground (humus or peat)
- adsorption - molecule: molecule adsorption of aliphatic and aromatic compounds to organic components of the ground
- liquid phase (insoluble or poorly miscible in water): mineral oil, petrol and organic solvents. Liquid occurs in the soil in droplet form or as a film surrounding the ground particles. In this type of pollution, the specific weight of the liquid plays an important part. Liquids that are heavier than water will form a layer above a poorly permeable layer, while liquids lighter than water will form a layer on the ground-water table.
- soluble in water: occurrence in groundwater
- gas phase: aromatics (BTEX), volatile components of petrol, diesel oil and other mineral oils, volatile chlorinated hydrocarbons.

### **Types of content**

The above pollution types can be divided up into a number different categories, which in turn can be categorised per industry sector.

Pollution types:

<sup>a</sup> J. Verschuren (1993)

- heavy metals and metalloids: chrome, cobalt, copper, cadmium, nickel, arsenic, zinc, tin, mercury, lead and antimony. Occur as metal and as oxide, sulphate, nitrate, halogenated, carbonated or silicate forms.
- complex cyanides and free cyanides
- aliphatic and aromatic hydrocarbon and mineral oils.
- volatile halogenated hydrocarbon: Trichloroethylene, Perchloroethylene
- non-volatile halogenated hydrocarbon: Polychlorobiphenyl (PCB), different types of pesticides
- other compounds: ammoniac, acids, lye, phosphates, sulphates, nitrates

## 6.6.7 Remediation methods

Remediation techniques have been under development in the Netherlands since 1980. As soil remediation is a relatively new technology, large-scale techniques are still being developed. Remediation methods can be categorised into two main groups, with a third group acting as a combination of the main groups<sup>385</sup>.

- soil recovery
- isolating the pollution
- combination of isolation and recovery.

### Soil recovery

Soil remediation by excavating, followed by soil purification or tipping.

The primary purification techniques<sup>386</sup> involve:

- thermal and extractive methods for removal and
- biological methods for alteration.

Tipping must be considered, if there are no adequate soil purification techniques for this specific situation<sup>387</sup>. Temporary storage is considered if the purification plant has a limited capacity<sup>388</sup>.

Soil remediation through in situ purification is currently under development. In addition to not having to excavate the ground, other advantages of this method include its relatively low costs and no interruptions to the company operations<sup>389</sup>. The techniques applied include flushing out the contaminated soil ("washing"), extraction of polluted air streams, chemical or biological conversion and removing pollution via an electric field.

Most contaminated soils are cleaned up by excavating, followed by soil purification. In situ soil purification occurs on a limited scale, but will become increasingly commonplace in future.

### Isolating the pollution

This process effectively involves containing the spread of the pollution. This can be achieved in a number of different ways<sup>390</sup>:

- installing vertical and horizontal screens, such as sheet piling, building plastics, mastic layers, bentonite-cement slurry walls etc.
- pumping up groundwater and/or infiltration water.
- using fixation techniques; immobilising the pollution.

Isolation is primarily used in cases of extensive pollution, where "hot spots" – places with the highest pollution levels - are isolated in order to prevent further spread before complete remediation, or in order to be cleaned up first<sup>391</sup>.

### Combination of isolation and recovery

In cases, where it is not (yet) possible to recover the soil for all types of pollution, the unrecovered areas are isolated.

## 6.6.8 Soil purification techniques

Soil purification methods are aimed at removing the pollution or converting the pollution into components that pose a minimal, or acceptable, risk to man and the eco system<sup>392</sup>. The latter method comprises biological degradation and conversion of the pollution. The characteristics, on which the soil purification process is based, are determined by the specific (chemical) properties of the pollution.

The most prominent properties are:

- phase: gas, liquid, solid (volatility, boiling point)
- solubility in water or in another solvent
- adsorption/absorption (electric properties)
- chemical stability
- thermal stability
- magnetic properties
- biodegradability/convertibility
- weight and form of the particles
- size and shape of the particles.

### Information needed for soil purification

In addition to the soil purification technique, the "remediability" of the ground also plays an important part, as soil purification comes with a price tag attached. Soil remediation experts will need specific information, such as the nature and concentration of the pollution, the presence of other contaminants and debris, plastic, cinders, vegetation remnants etc. Knowledge of the soil in terms of grain-size frequency distribution, organic dust content and moisture content are also essential factors in the world of soil purification.

This chapter will focus on the following purification techniques:

- techniques for excavated grounds;
- in-situ soil purification techniques;
- isolating contaminated sites.

### Thermal soil purification of excavated grounds

Thermal soil purification involves increasing the temperature of the ground to such an extent, that the contaminating substances are evaporated and/or decomposed and evaporated. The techniques used during this process fall outside the scope of this dissertation.

Application: all types of organic contaminations.

In principle, this method can also be applied to heavy metals and their compounds, provided temperatures reach approx. 800° C.

Thermal soil purification can be applied to any type of ground. However, grounds with (a high content of) organic material will be susceptible to burning. Clay and loam grounds require more energy for this process than sand ground. Furthermore, measures must be taken to guarantee a uniform ground supply.

In thermal soil purification, the contaminated substances are evaporated, and the vapours filtered. The resultant emissions are subject to severe criteria under the Wet op de Luchtverontreiniging (Air Pollution Act).

### Purification through extraction of excavated grounds

The extraction process is divided into a number of phases:

- putting the contaminated ground into contact with extracting agent (dissolved in water)
- separating extraction particles from the clean ground through rinsing out
- purifying the (contaminated) extract

Application: suitable for removing heavy metals, metal compounds and organic pollution.

This method is ideal for purifying sand soils, due to the proportionately low adsorptive forces between sand grain and contaminant. Due to the relatively high adsorptive forces of clay and loam grounds, this method is unsuitable, or less suitable, for these ground types.

### Biological soil purification of excavated grounds

In this process, organic contaminants are decomposed or converted by micro-organisms into compounds that are not harmful, or virtually harmless, to man and the eco system.

A distinction is made between a mineralisation process with anorganic end products, and degradation with incomplete mineralisation.

These biological processes are however known to cause highly toxic inorganic compounds such as chlorinated derivatives due to the decomposition of organohalogenes. It is of vital importance that employees working on site be adequately protected.

This biologic soil purification method is based on landfarming and bioreactor techniques.

In landfarming, the contaminated ground is spread in a thin layer across a suitable terrain and cleaned by natural microbiologic processes. The degradation process is stimulated by adding oxygen, cultivating the ground (ploughing), adding lime and nutrients for the decomposing organisms, and by proper water management.

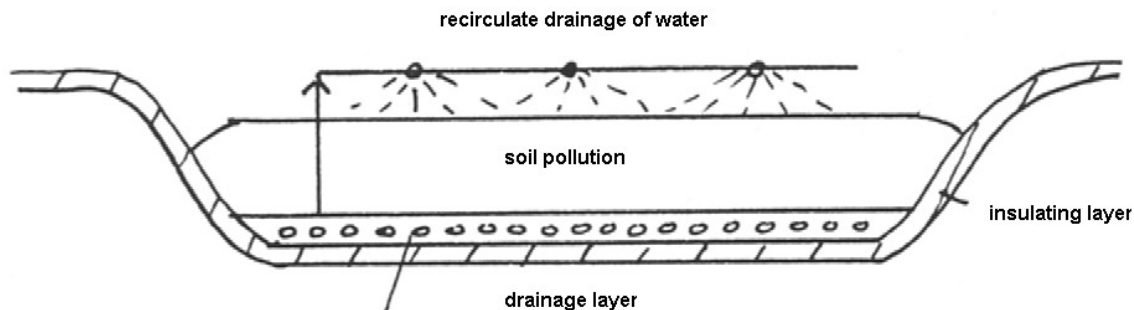


Fig. 1041 Landfarming diagram

### Bioreactor techniques of excavated grounds

We can identify two bioreactor techniques: a dry form, comparable with composting solid waste, and a wet form in so-called soil slurry reactors.

This technique can only be applied to organic compounds.

In principle, this method is suitable for all ground types, but is usually applied to sand grounds due to its high permeability and ease of cultivation.

The disadvantages of this method include the long duration of the soil purification process, and difficulties in reaching the target values.

### In-situ soil vapour extraction

Volatile compounds are removed by extracting soil vapours, and subjecting them to surface clean-up. This process is known as soil vapour extraction, and is solely applied to volatile substances such as perchloroethene, trichloroethylene, petrol, benzene, toluene, xylene, ethylbenzene and methylene chloride.

This method can only be applied to permeable grounds such as sand.

Disadvantages include difficulties in reaching the target value, longevity of the process (can take several years) and, in the case of mineral oil, the leftovers of heavy components.

### In-situ bio restoration

The process of bio restoration consists of optimising the conditions for micro-organisms responsible for ground purification.

This method is primarily applied to sand grounds, as the contaminant must be easily degradable. As a result, this method is mainly used in pollution types involving mineral oil and low molecular weight polycyclic aromatic hydrocarbons.

This method also has its disadvantages: it takes a long time to achieve the target value, if it is achieved at all.

### In-situ liquid extraction

Contaminants are extracted from the ground through the infiltration of a water-based extracting agent, causing a chemical reaction. The extracting agent, containing the dissolved contaminants, is then pumped up and cleaned above ground. Liquid extraction can continue until the desired target value has been reached.



Application: primarily in easily permeable grounds such as sand grounds. This method is suitable for all pollution types that are soluble in extracting agents, including heavy metals, low molecular weight polycyclic aromatic hydrocarbons, low molecular weight halogenated solvents, phenol and benzene.

The total duration of this process ranges from several months to several years. It is not always possible to achieve the target value.

### **In-situ electro reclamation**

The method of electro-reclamation is based on three direct current transmission lines: electro-osmosis, electrophoresis and electrolysis.

Ions or ion complexes are transmitted through liquid between the soil pores under influence of an electric field. This causes the polluting ions to be carried to the electrodes and removed via a pumping system.

Application: this method is ideal for purifying clay soils contaminated by heavy metals. Its main disadvantage however is its energy inefficiency.

### **Conclusion in-situ soil purification techniques**

The above in-situ soil purification techniques are currently operational in the Netherlands. A certain degree of experience has been gained with most of these techniques, in particular underground contamination and polluted petrol stations. At present, it is virtually impossible to achieve the A value using these techniques. Furthermore, they are only suitable for homogenous areas. The remediation methods take a relatively long time to implement. Having said that, these in-situ soil purification methods also have a number of advantages, including underground remediation, tackling deep contaminations without the need for earth moving, and causing minimal disruption.

It is clear from the above, that researchers in the Netherlands are currently on a steep learning curve in terms of remediation techniques, learning from every new piece of technology, unveiling new and at times unexpected information. In my opinion, promoting in-situ soil purification is highly desirable, given its advantages. One solution would be to increase the costs of tipping, and inspecting tipping activities. It might also be useful to carry out a feasibility study into the use of A-value as a follow-up remediation value. Greater flexibility in remediation policy would promote the use of these relatively simple techniques.

### **Isolating the contaminated sites**

A polluted soil is screened off, thus containing the spread. This method can involve closing off the site and preventing potential spread via soil vapours.

### **Civil-engineering isolation techniques.**

This civil-engineering isolation technique is based on the erection of impermeable walls of steel, bentonite-cement slurry walls and grout curtains. Preventing sideward spread alone will not suffice, as the upper surface and lower surface must also be isolated.

This technique can be applied to all areas. Disadvantages include the behaviour of isolation walls in the course of time. Only steel walls are moveable.

### **Geo-hydrologic isolation**

Geo-hydrologic isolation involves pumping up the groundwater of a contaminated site, preventing the spread of pollution in the groundwater. This pumping action can be combined with water infiltration from an adjacent area.

Application. This technique is difficult to apply in built-up areas, as soil layers are generally prone to settling during water drawoff. The degree of settlement depends on the ground type.

This technique releases (lightly) polluted water that needs to be discharged. This cannot simply be done into a sewer or open water, so the water has to be cleaned prior to discharging.

### **Site management and inspection**

All the above isolating techniques require adequate site management and inspection, even in the event of (partial) failure of the technique.

### **Living layer in urban areas**

A special isolation method is being applied to a number of urban areas. Ground that is proving difficult to clean due to the surrounding buildings, is isolated from all sides. The overburden is partially excavated and isolated. A layer of clean ground, known as the living layer, is applied on top of the insulating layer. When using this terrain for building work, care must be taken that this upper insulating layer is not "infiltrated". This method is currently being applied in the city centre of Amsterdam.

### **General conclusion remediation and soil purification techniques**

One of the biggest problems associated with contaminated sites is that they contain a significant amount of urban, industrial, building and demolition waste in addition to polluted ground.

Pollution is rarely of a singular nature; it is usually characterised by a combination of contaminating substances, which frequently need to be extracted in different ways from the ground.

Some substances are impossible to extract from the ground, or require extraction methods that have not yet been discovered. In this case, isolation is currently the only solution available.

### **Combining soil purification and site preparation**

Purification of contaminated soil requires a lot of shifting of the ground. As such, might it not be wise to draw up a plan of approach for preparing the site, as well as a soil purification plan, and effectively combine these two plans? The underground infrastructure can be installed during or immediately after clean-up.

In instances, where a site is located in the middle of a remediation area, where space is at a premium, this combined approach can yield some surprising results.

### **Involvement of experts**

The follow-up investigation can be carried out by anyone, provided this is done in accordance with the exploratory survey and follow-up investigation protocols, and the requisite details and documents have been submitted in report form to the relevant municipality. It is however recommended that the relevant surveys are carried out by an expert. Soil samples may prove problematic; these can be analysed by specialist laboratories in accordance with the methods indicated. (A list of ground survey laboratories has been included.)

Technical laboratories carrying out these surveys have acquired a certain reputation in this field and are therefore often readily accepted as authoritative by local authorities. These laboratories usually include an executive body, leading to a conflict of interests.

## **6.6.9    Appendix saneringsregeling wet bodembescherming P.M. (remediation regulations under the Soil Protection Act)**

# 7 Legends for design

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