38 CLASSIFICATION AND COMBINATION

YPE CUPERUS

Different ways exist for classifying components. Each classification serves its own purpose. This Chapter discusses several classifications. In a design for a building, components are combined into an ordered whole. The ordering of the positioning and size of the components constitutes the essence of the design, execution and usage of buildings. In order to be able to classify, the components should first be brought under the same nomer. Classification is the condition for combination.

Every classification of components generates problems of definition: should a floor be regarded as a load carrying component? For a floor is featuring a separating function as well. And should the walls always be regarded as separating components? Some walls are displaying a carrying function after all. By the same token, a global distinction between carrying and separating does not suffice: the classification should be worked out further; and this leads readily to complicated classifications of components and their definitions. In addition, the number of kinds of connections between all these components is growing. Perhaps these should be distinguished further in connections with the forms of points, lines, planes or three-dimensional structures; each of them with carrying and/ or separating functions; or both. But is it not better in that case to regard the connections as starting point, while defining the components between them? The focus shifts then to the 'building node'.

First, different classifications are described as seen from the practice of education, building and research. Next, an ordering of the combinations of components is explained as related to the history of the origination of modular co-ordination for building in The Netherlands. The shift from building to fabrication and assembly caused an inquiry into another, new classification of the components. The state-of-the-art of the most recent building node study is described. This is the foundation for consumer-orientated, industrial, flexible, decomposable and thereby sustainable building.

All the classifications demonstrate a range of scale overlapping with the semi-logarithmic range of nominal radii and their nomenclature earlier mentioned in the present book.

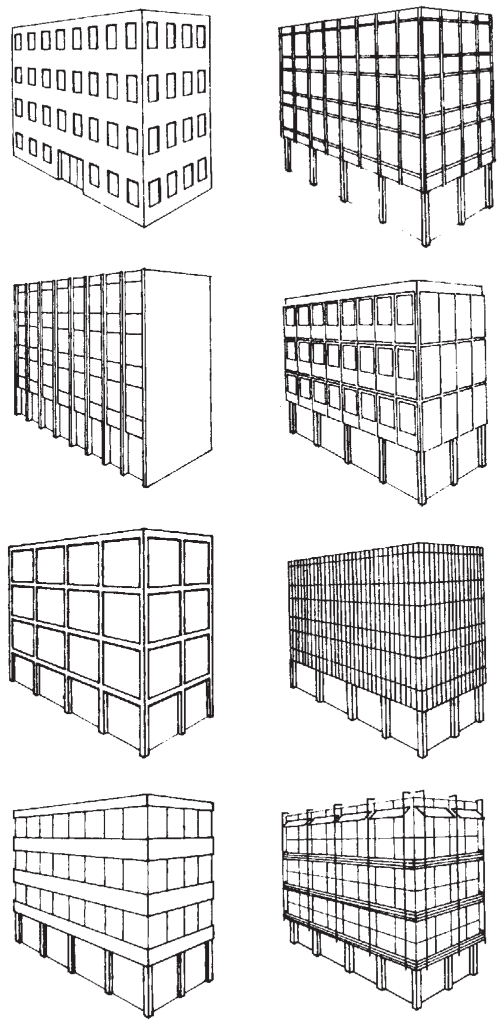
Nominal radius	Name
30m	Building complex
10m	Building
3m	Building segment
1m	Building part
300mm	Building component
100mm	Superelement
30mm	Element
10mm	Subelement
3mm	Trade material
1mm	Composition material
<1mm	Material

Both within the Faculty of Architecture of Delft University and outside it, different classifications of components have been used in education over the years. Building practice employs its own. These classifications will be described here; starting with those of a book dearly beloved at the Faculty of Architecture.

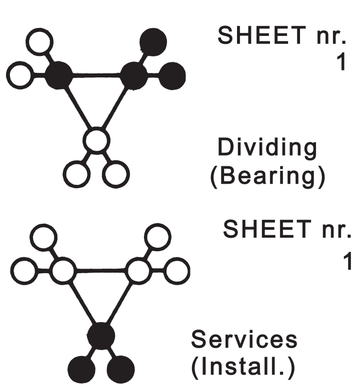
38.1 ACKERMANN'S CLASSIFICATION

The book '*Grundlagen für das Entwerfen und Konstruieren*' (Basic Principles of Design and Construction) by Kurt Ackermann deserves sincere appreciation because it defines, in 150 pages, very many aspects of the technical design of buildings. The author discriminates between spatial structuring (planning, design, dimension control systems), function (placing the different functions in relation to each other, and their connection to corridors, stairs and elevators), load-bearing constructions, divided according to their composition principle (column versus load-bearing wall), type of building (high-rise, single storey), but also main building elements (foundation, roof, façade, etc.) and material (timber, steel, concrete, etc.). Further, he treats physics as applicable to buildings, construction connections and technical installations. He concludes with the subject 'form'. The book, the product of one person only, takes a didactic approach to architecture and construction, starting out with technical issues which lead finally to the definition of form.[a]

a Ackermann, K. (1983) *Grundlagen fur das Entwerfen und Konstruieren*.



353 Structure according to Ackermann



354 Subject coding according to Gout

At Delft University, every subject in the structuring by Ackermann has its own specialists who, as a team, teach and carry out research on technical aspects of design and building. Until 1975, the Faculty of Architecture comprised five sections dealing with building-technical matters: three for ‘Building Constructions’ which followed the yearly curriculum (first and second year; third year; forth and fifth year), the Section Industrial Building, sub-divided according to construction material (concrete, steel, timber), and the Section Applied Mechanics. These last two sections were more orientated towards design and were part of the annual curriculum.

38.2 EDUCATIONAL CLASSIFICATIONS

To bring some order into the growing volume of building-trade data, In the seventies, Gout, a Professor of building technique, used a system that differentiated between ‘partitioning’, load-bearing’, and ‘facilities’, crossed with a division according to ‘function’, ‘materials’ and ‘construction’.[a] After 1979, this system was no longer used and lecture notes again became more traditional, addressing principles and particular solutions in architecture and building design.

In 1977, Dijkstra defined ‘integration levels’: the first integration level is that of basic knowledge (like applied mechanics, physics as related to buildings), the second integration level deals with the knowledge and practice to integrate various building-construction disciplines on the level of an actual building design. Dijkstra taught the second level of integration in his legendary project lectures, in which, for eight consecutive weeks, the project design and the implementation were explained by people with hands-on experience.[b]

During the eighties, a simpler structure for the department was put into place, related to graduating specialities, in which technical installations and physics as applied to buildings (and, temporarily, building economics) formed the sub-department group Architecture and Urban Technology (AST). This structuring, based on the way teaching was organised, was provided by successive professors and staff members who often had earned their spurs in practice, not in research or teaching.

In the course of time Chairs were modified, like the change of the Chair ‘Materials and Creative Design’[c] to ‘Product Development’ (Eekhout). Teaching activities always followed the structuring according to integration levels, whilst changing the definition of tasks and fields of activity of the chairs made it possible to stay in touch with real-life.[d]

Brouwer, Professor in Building Technology from 1991 to 2000, pleads for integration. Then it will be possible, by clever design, to combine functions, for instance in a façade panel. By providing the parapet of a façade with a combined heating / cooling / sun-shade system, which works independently from the rest of the building, it is possible to save money on large installations and related space requirements of air ducts, where additional expenditure follows from thinking in separate systems.[e]

In design, an almost endless series of decisions is required before the built environment actually comes into being. Trotz, Professor of building technique from 1994 till 1999, ordered these decisions by category and translated them into a checklist, which the various parties, under the direction of the architect, can go through. Because the check list, in first instance, is written on the process and not on the end product, the list is long, regardless of the size of the result.[f]

The architectural field can be structured in many more ways, for instance according to type of production (once-only or industrial), discipline (foundation, façade, roof, etc.), scale, sequence, economics, culture, time, environment. All systems of structuring serve their own purpose and, because the building industry serves many purposes, no particular system of structuring is optimal.

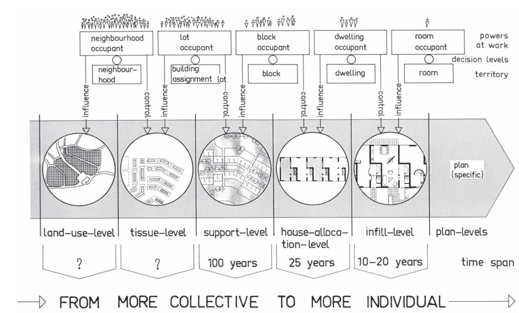
a Gout, M. (1973) *Bouwmethodiek I. 2e bundel*.
b Dijkstra, T. (1970) *Gebouw Afdeling Bouwkunde TH, Berlageweg, Delft, bouwkundig ontwerp.*
c Zwarts, M.E. (1983) *Bouwmethodiek 1*.
d Woord, J. van der (1994) *Een kleine historie van het vak op de faculteit*.
e Haartsen, J., J Brouwer et al. (1999) *De intelligente gevel*.
f Trotz, A.J. (1999) *Lamme hand achter blinde vlek?*

38.3 BUILDING-TRADE CLASSIFICATIONS

The Netherlands Building-trade Documentation (NBD) is a loose-leaf system of product information. It uses the SfB classification system. The NDB describes it as follows: *"It is a classification system for all information relevant to the building industry. This system was developed in Sweden in 1950 and has been accepted internationally"*. The system divides the building process into: substructure, superstructure, completion, finishing, provisions for installations, standard layouts, variable fittings and building site. All data 'relevant to the building process' is placed in one of these groups. The system uses an extensive letter / numbering code.[a]

The Standard Specification for Housing and Industrial Buildings (STABU) uses its own system for the classification of products. This system is geared towards writing specifications.

Typical for the classification of products is that, by rigidly staying with the system, the 'General' section keeps on growing, because very many items either do not fit one particular section or belong in more than one section. For instance: should data on sun-shades be placed in the category 'sun-shades', because they are sun-shades, or in the category 'façade systems', because sun-shades are procured and installed by the supplier of the façade, or under 'aluminium', because the sun-shade contains aluminium parts for which the specifications contain general conditions?[b]

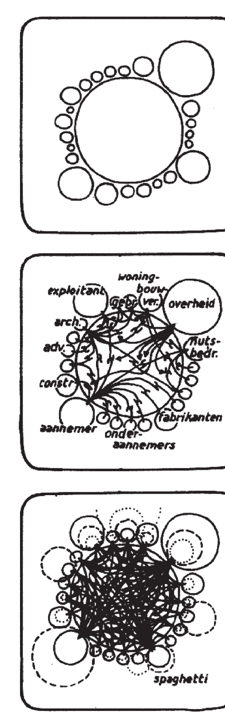


355 Levels of decision making

38.4 CLASSIFICATION FOR DECISION-MAKING

Instead of dividing the building trade according to 'things', there is much to be said for making a division based on the parties that decide over these 'things'. This idea was worked out for the first time in the beginning of the sixties by Habraken and the Foundation for Architectural Research (SAR), Eindhoven, at which time 'support' and 'infill' were defined. The support is that part of the building about which the inhabitant has no say and the infill is the part about which the inhabitant has full say.[c] Later, other decision making levels were identified, like 'tissue', refering to town planning.

Van Randen, Professor for building technique from 1973 till 1991, further detailed the sub-division of the decision-making process. He described the building process as the 'spaghetti-effect': pull one strand and everything starts to move in an arbitrary way.



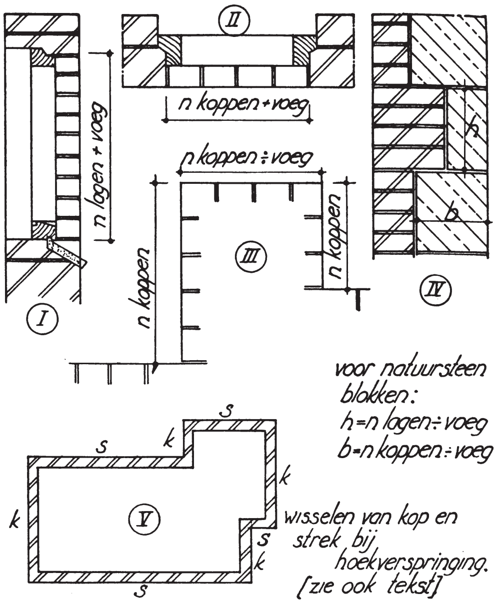
356 Van Randen characterised the power game in the building process as 'the spaghetti– effect'

Because decisions by the parties involved result, in the end, in decisions about materials, it was proposed to 'un-couple' building elements by proposing rules for location and size of the building elements.[d] This led to extensive research into modular co-ordination in house building, resulting in yet another classification of components. The basis was division of a building into 'building parts'. The groups of building parts defined were: load-bearing walls, floors, roofs, façades, inner-partitioning and wall lining, equipment, ducts and services and spatial areas. By agreeing, for each building part group, on certain rules about dimensions (multiples and parts of 30 cm) and locations (on an imaginary grid), the freedom of choice for the various parties involved would be exactly known, and this would make the building industry more efficient.[e]

The division into building part groups, intended for structuring the building process, was also used in teaching. The building technique was explained using 'double pages' with, on the left page, the general considerations and, on the right-hand page, the specific solutions.[f]

When the components to be used are known, they must be combined within a plan for the building. This could be achieved by using mathematical models. In architecture this usually happens by a design process. During building the components are connected to one another. Connecting, joining, linking, coupling, fitting or interface determine whether a combination works. Sizing and positioning of the components establish the complement of the connection. Since the beginning of the sixties elaborate study into this has been undertaken; under the umbrella 'modular co-ordination'.

a NCA Vakdocumentatie (1999) *Nederlandse bouwdocumentatie*.
b STABU, Stichting (1999) *Standaardbestek Burger en Utiliteitsbouw*.
c Habraken, N.J. (1961) *De dragers en de mensen, het einde van de massawoningbouw*.
d Randen, A. van and L. Hulsbos (1976) *De bouw in de knoop*.
e NNI, Nederlands Normalisatie Instituut (1981) *NEN2883, Regels voor gecontracteerde experimenten met modulaire coördinatie voor de woningbouw*.
f Randen, A van (1979) *Dakdiktaat*.



357 Koppenmaat

38.5 SYSTEMS OF COUNTING AND MODULAR SYSTEMS

Systems of scale and measure are significant for building in two ways. In the first place, they are a system for counting. All sizes may be expressed in the system of units chosen. But, even since early days a second application demonstrated itself: a modular system. Then, the rôle of the measuring system does not stay limited to counting. It has consequences for the positioning and sizes of the building element itself. The brick with its derived measures for length, width and height provides a classical example.

Modular systems entail great advantages for communication, since they allow standardisation. Not only the brick itself, but different building elements could be expressed in an earlier stage in these measures.

This standardisation enabled pre-fabrication. A carpenter could make sliding windows with a reasonable certainty that they could be applied in projects. A commission for a window-frame could be formulated simply in a number of heads and layers. This enhanced communication enormously.

In the early days the measure of heads and layers were just regionally significant, since the shape of the brick varied per region. Then, following the Building Law of 1901 that caused the emergence of a national building market, the ‘Waal’ format proved to be triumphant with a layer thickness of 6,25 cm. Sixteen layers make one metre: the modular system (brick module) and the counting system (the metre) were coupled.[a]

38.6 MODULAR CO-ORDINATION AS AN INTERNATIONAL NORM

After the Second World War modular co-ordination was getting new impetus, also a new basis. During the industrial effort connected with the war a vast body of experience with mass-production came into being. The merits of standardisation were discovered. These achievements should also be employed in building: not only for rapid re-construction, but also to build a counter-weight in Western Europe against threats from behind the Iron Curtain.

The ISO, the International Organisation for Standardisation, was called into being with for its aim world-encompassing uniformity of normalisation. The NNI, the Netherlands Normalisation Institute, is member of ISO.

The new basis for modular co-ordination in building was fixed by ISO on a basis module M of 100 mm and a preferential module of 3M, 300 mm. In this way a synthesis of the metric system and the anthropomorphic system of inch, foot and yard came into being. This way, 100 mm is roughly 4 inches and the preferential module of 300 mm is rounded off to 1 foot. That industry influenced modular developments greatly can be explained from the history of the rise of ISO. The options were determined by producing, rather than by those prevailing while building. Industrial considerations, like assortment restriction were rampant. Architectural conditions, like simple joining and inter-weaving – and the forming of spaces as well – was subservient to it.

Almost all industrialised countries prescribed a norm for modular co-ordination in building on the basis of the ISO guide-lines. The version of the Netherlands was published in 1964. It is a two-page document, NEN 5700, wherein just the basic module M of 10 cm is fixed and a system of reference, ‘a three-dimensional grid of planes perpendicular to one another on a mutual distance equal to the basic module M. This system serves as a point of departure for the positioning of all building elements’. One year later, a norm was published, entitled ‘Modular Co-ordination for Building. Tolerance System’. In it, the concepts related to tolerances were defined, like placing a modular building element in the grid, tolerance of manufacture, positioning tolerance, maximal and minimal impact of joining.[b]

38.7 THE IMPORTANCE OF CO-ORDINATION OF POSITIONING

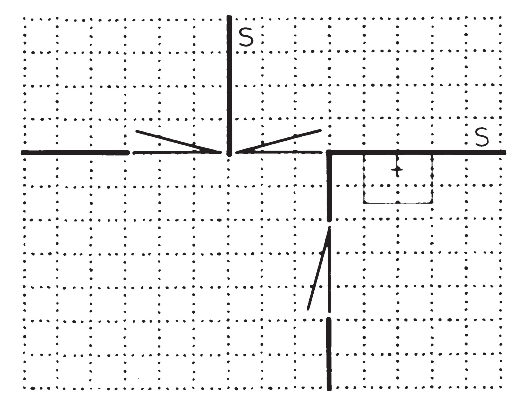
Modular co-ordination in building in the Netherlands took a turn differing from those in other countries. Architects were feeling ill-at-ease with norm NEN 5700, given its undefined deter-

a Carp, J.C. (1983) *Modulaire coördinatie, een hele geschiedenis*.
b Idem.

mination of position. The architect is not developing products, but designing buildings. By the same token he is not dealing with parts, but the whole. Joining, inter-weaving and forming of spaces are essential problems to him. All solutions should be studied for three-dimensional consequences; also on positions very distant in the building. Therefore, it is important that the elements do have a fixed position. Differences in size should not lead immediately to adjustments, having an inclination to reproduce themselves well into the remotest fringes of the building. In addition, a second characteristic of the work of the architect is important. Each and every design is always developing in steps. The interest of the architect is entailing that each subsequent step does not undo the previous one. This adds to the importance that the elements are staying in place. Further detailing to be considered may not trespass on positioning of building elements.

Then, a variant on the ISO proposals was generated among architects in which positioning was called for. It departed from an alternative modular grid with a one-to-one relationship between modules M and 3M: the M was positioned at the heart of the 3M grid-lines. These were the proposals of SAR, *Stichting Architecten Research*, a group of architects interested in furthering industrial ways of production in residential building; amongst other aims. The modular proposals had to enable separation between 'carrier' and 'appurtenance'. The emancipation of the appurtenance and equipment was seen as a way to create a space where the resident may decide for himself.

The SAR proposals were well received domestically; and outside the country. They also caused dis-enchantment. The positioning leap of 3M was experienced by architects as huge, particularly in residential building. Producers were of the opinion, that the SAR proposals were veering too much into the direction of positional fixing. The fixing of measuring was deemed to be left in jeopardy.[a]

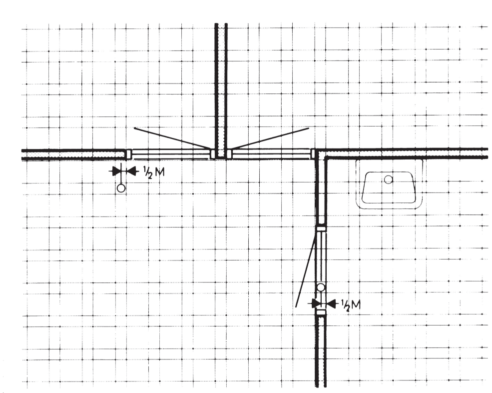


358 Spatial floor plan according to NEN2883

38.8 SYNTHESIS OF POSITIONING AND MEASURING CO-ORDINATION

The new interest as well as criticism caused the NNI to re-install the Norm Committee. Norm NEN 2880, '*Modular Co-ordination in Building*' was published in 1977. The positioning systemising of the SAR was endorsed and a lot of attention spent on the determination of measurement. A '*modus operandi*' was proposed, how sizes could be deduced. As far as the determination of sizing is concerned, NEN 2880, however, was rather a methodology than a norm.

By the massive production in residential building in series, the need emerged for a norm regulating the determination of proportioning in residential building more precisely; this became NEN 2883, '*Modular Co-ordination for Residential Building*'. It may be regarded as a synthesis of the developments described above. The norm regulated positioning as well as sizing prescriptions and was furthering as such the interests of builders as well as producers. It did enable the architect to work from what is global to what is detail, and to change building material in a later stage, since the co-ordination of positioning prevented that changes in size were transferred, 'radiated' to elements elsewhere in the building.[b]



359 Material floor plan according to NEN2883

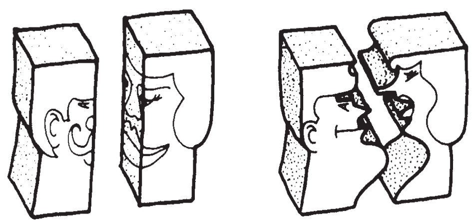
The norm disconnected carrier and equipment; so that separate parties could decide independently within their own range of influence. The tuning of sizing and positioning also allowed that different disciplines could work next to one another during construction.

The consequences for products and ways of producing have been studied carefully in extensive consultation with industry. The norm distinguished between different 'partial building groups', like carrying construction, roof, façade inner walls, etc., all suggested by different disciplines with their own conditions and requirements. The spatial norms to be attained in residential building were included in the considerations as well, since minimal sizes of spaces are often dominant over the sizes of materials. 'Space' was one of the partial building groups.

In spite of all these advantages, NEN 2883 had to face resistance in building practice. The rulings determining measure and position were rather abstract and kept themselves aloof

b Carp, J.C. (1983) *Modulaire coördinatie, een hele geschiedenis*.
c Idem.

from the practice of drawing boards and building site. At the time the norm should start to apply, the building industry was faced by serious recession, so that it could impossibly invest sufficiently in the apparatus of production. By increasing automation in production due to CAD / CAM and the logistics of Just-in-Time Delivery, the urgency of restriction of assortment was smaller than during the initial period of modular co-ordination. NEN 2883 was replaced in 1986 by NEN 6000, *'Modular Co-ordination for Buildings'*. Once again, this one was written in the spirit of the time-honoured ISO guide-lines. This particular norm was never made obligatory and is not applied in practice.[a]

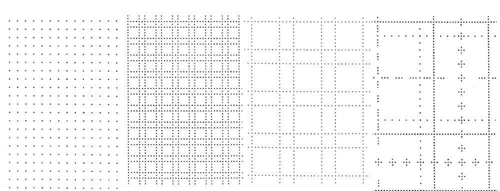


360 Adjoining and penetrating connections

38.9 FROM DE-LINKING TO INTERFACE

The synthesis of size and place co-ordination served design and execution because changes in size on one place were not transferred to places elsewhere in the building. For the fitting of the parts suggestions were given: do not make penetrating connections, prevent 'boys meet girls'. This hint also contributed to prevention of the 'ripple effect'.[b]

Without adhering and closure no building can emerge. For that purpose an elaborate handbook has been developed, explaining how the spatial plan could be drawn subsequently on a 3M line grid (design grid 1:100), how, on that basis, the material plan could be drawn on a 1M-2M bandwidth grid (notation grid 1:50) and subsequently the details on a grid with a granular size of 1 mm (detail grid 1:5).[c]



361 Four different grids, illustration from the handbook.

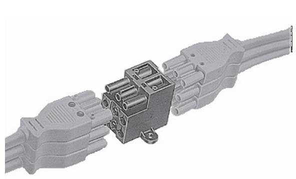
The rules of sizing and positioning co-ordinate the elements and to a lower degree the connections between the elements. These were solved in first instance in the drawings ('to be decided on'), in second instance during construction ('saw off').

Government is de-regulating and has withdrawn itself from residential building. The Building Decree does not prescribe norms for details, but for types of performance of the building. The requirements put to the building in terms of safety, comfort and endurance are high. The quality desired of the components to be applied can be reached better under the controlled conditions prevailing in the industrial plant than in the wind and weather of the building site. The component has ceased to be the weakest link; now it is the interlocking of the components. The attention has shifted from position and size to inter-connection or interface.

362 Building on the site

Rulings for the interface are implicating an important condition for independent product development and building with sub-systems, like an entire roof delivered on site, or a façade system. In order to be able to use a computer for designing products and connections and to select from the database of existing products, an abstract description is needed allowing the computer to search and select. Next, inter-dependencies between the building parts can be named. Then, making the building parts independent can be a condition for more efficient production.

Manufacturing and building are two ways to make a product. Manufacturing happens in the industrial plant, building on the site. If manufacturing leads to an improved price-quality ratio than building, why do we not stop building and are we not making buildings just in the plant? The answer is obvious. Buildings are bound to sites. At best, we can shift the balance between building and manufacturing (pre-fabricating). The part of the building to be connected to the site (the foundation) may be comprising pre-fabricated parts like poles and beams, but the instalment happens on site. Many constituent parts just need installation. Building is becoming assembling. In order to be able to assemble, there should exist pre-fabricated products as well as the certainty that they will fit on their position. Improvising on the site does not provide that certainty; plugging- in and interlocking does.



363 If it clicks, it is alright

In addition a well-designed interface renders the service of a built-in quality control: if it clicks, it is alright; and a plug-connection not well-made may be recognised and improved upon. This way the hiding of shortcomings is made impossible.

a NNI, Nederlands Normalisatie Instituut (1986) *NEN 6000, Modulaire coordinatie voor gebouwen*.
b Randen, A. van and L. Hulsbos (1976) *De bouw in de knoop*.
c Project Group MC+B (1980) *Modulaire coördinatie: plannen & details volgens NEN 2883*.

As long as there is no consensus on the interface no good products can be developed: that was the subject of the *'Building Node Study'* conducted during the nineties.

38.10 BUILDING NODE AS AN INTERFACE

In a design process from global to detail, general decisions may be formulated during an early stage in a spatial plan, with, in it, material boxes, spatial reservations for components with a certain performance. The performance, for instance thermal isolation, does not only extend to the components, but also to the joining between the components. In order to be able to classify the connection, the components should also have the potential to be named. For this, existing classifications proved to be inadequate. A new classification was needed that can name the components according to their position and size, the x, y and z co-ordinates of their spatial boxes, the performance required and the inter-connections.

This classification is establishing the basis for description of the interface in terms of performance. Furthermore, it allows searching in the database of available components on the basis of performance description, while matching the best possible performance to the spatial box for which the performance was specified.[a]

38.11 CLASSIFICATION ACCORDING TO POSITIONING

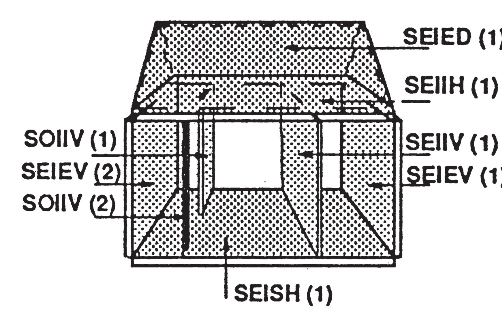
Parts and connections make a building. It may be described by points, lines and planes (x, y and z) as a concatenation of volumes. Some volumes are spaces, other volumes contain material. Such an abstract description enables description of a building without referring to specific products or connections. Based on its position, a unique code may be given to each part of the building, like S-EI-EV-(1). This code comprises a combinations of letters: in sequence prefix (S), first position (EI), second position (EV) and postfix (1). In this context one may distinguish between space-separating and non-space-separating parts. The first type, for instance an outside wall, inner wall or floor, is termed SE (space enclosure), the second, for instance a column or a kitchen cupboard a SO (space occupier).

A space separating part may separate an inner space from outside (IE), two inner spaces from one another (II), an inner space from the soil (IS) or from water (IW). A space separating part may then be placed horizontally (H), vertically (V) or at an angle (D):

Separating	Outside	Horizontal	SEIEH
		Vertical	SEIEV
		Angle	SEIED
	Inside	Horizontal	SEIIH
		Vertical	SEIIV
		Angle	SEIID
	Soil	Horizontal	SEIBH
		Vertical	SEIBV
		Angle	SEIBD
	Water	Horizontal	SEIWH
		Vertical	SEIWV
		Angle	SEIWD
Other			SO

364 Separating

The collection of materials within a volume is termed a 'group'. An example of a group is an inner wall. Its parts are not always homogeneous; a window or a door may be located in it. A group may comprise several sectors. A sector is a 'sub-group'. To indicate that the code does not refer to the group as a whole, but to a part, the prefix (sector) is used. Many groups and sectors demonstrate a tiered structure. These tiers can become part of the code.



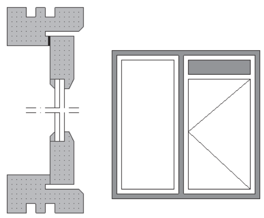
365 Group level

Computer programs may be developed, on the basis of a building drawn on a computer, coding automatically all parts. It is clear that this does not lead to user-friendly codes. However, they are unambiguous; and the computer knows how to deal with them. Just as a bar-code reader may tell us what information is hidden in the bar-code, an alias may be associated to a code, not readily recognised by the human eye.

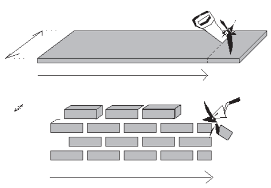
Spatial information in the form of x, y and z co-ordinates may be added to the coded parts together with additional performance requirements, such as desirable strength, fire proof, isolation in terms of heat and noise, colour, maximal price, and their likes. On the basis of this information the database of available products may be searched for optimal products, that may be drawn then as desired in the appropriate material box. Alternatives may then be drawn and compared, and the total price calculated. Ordering lists may be generated and on-line sent to providers, who then on demand and just in time.[b]

The abstract description can also be the basis for defining the interface. Materials are also differing in the degree in which they can adapt themselves to their environment. That is why a product description is also needed.

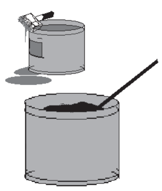
a Kapteijns, J.H.M. (1992) *Het informatiseren van het ontwerpen van bouwknopen;* Kapteijns, J.H.M. (1997) *Systematische productontwikkeling voor de bouw*.
b Hartog, P. den (1996) *NodeIT*.



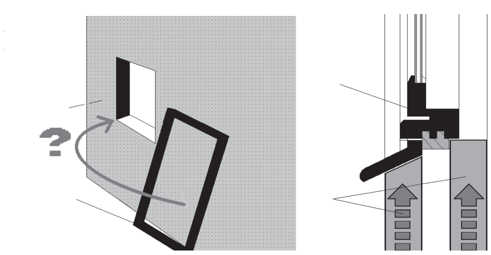
366 Part



367 Form



368 Material



369 Fitting problem and no fitting problem

38.12 CLASSIFICATION ACCORDING TO ADAPTABILITY

Many pre-fabricated products can not be adapted without damaging them unacceptably; think of pre-fabricated concrete or posts of doors and windows. These products are given the code P (part). Other products, like brick, wooden parts and planar materials are precisely used since they allow cutting or sawing on the building site, in order to make a measured fit. The products are given the code F (form). And then there are products delivered to the site as a material that will get final form only following processing; like concrete poured on-site, cement, paint, foam and their likes. These products are given the code M (material).

Earlier it was explained why it is that fabricating is better than building. In realising a building it is always necessary to build. A large share of pre-fabrication requires a lot of co-ordination, becoming more complicated with increasing numbers of suppliers. In the assembly of automobiles many suppliers are employed, but the location of production and the final product remain constant. In the assembly of buildings the site of production differs per building in terms of accessibility, and therefore of the providers. That is why the final product is different each time. In addition, different products demonstrate different sizing tolerances. For instance:

- a frame (P) in a pre-fabricated wall of concrete (P) must fit well; or it does not fit at all;
- the brick work (F) surrounding a positioned frame is adapting itself readily and, therefore, requires less tuning in advance;
- a wall decorated by carpentry must be sawn to size (F); - stucco and paint (M) always fit.

38.13 POSITION AND ADAPTABILITY COMBINED

The abstract description has a bearing on the space reservation for the material in a building. A distinction is made between the building (B), the space reservation for material: group (G), a subgroup; sector (S) and a tier, or layer in a group or sector (L).

The product description concerns the degree of adaptability of a product and is expressed in part (P), form (F) and material (M). We can now assess the building according to the degree of building and fabricating, by confronting both descriptions in a matrix:

	P	F	M
B			
G			
S			
L			

A traditionally built residence leads to the following distribution: Only the frames (sector level) have been pre-fabricated, made in the carpenter shop (P), the rest of the residence is on a low level (L) made on the building site (F, M).

	P	F	M
B			
G			
S	x		
L		x	x

A mobile home leads to the following distribution:
The entire building (B) is pre-fabricated (P) and is positioned on a pre-fabricated (P) foundation (G).

	P	F	M
B	x		
G	x		
S			
L			

A traditionally produced building is focusing on the right bottom part of the matrix, a pre-fabricated building on the top left.

The abstract description enables us to link the space reservation for the materials to the performance requirements and to find the optimal product substitutes. When appropriate products have been found for the empty fields, this is as yet no guarantee for a sound building. In the case of building, as well as in the one of assembly, there are certain dependencies between the products found that should be examined further.

38.14 DEPENDENCY DIAGRAMS

A building is a connected whole of building materials and building products. The connection transforms a collection of products and materials into a building that works. At the same time, the connection restricts the flexibility of the building, during construction as well as usage. A computer programme has been developed allowing analysis of the dependencies between various parts of the building. It can be provided in a dual way with building parts relating to one another, for instance: floor – door frame; frame door.[a] The dependencies of a part of a residence have been pictured, by naming the building parts relating to one another dually. The building parts (equipped with their Part-, Form-, or Material quality) are represented alongside, in the sequence of applying.

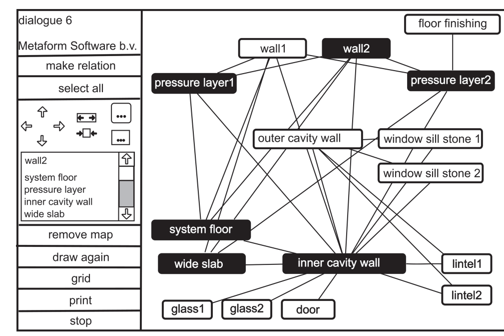
	Building part	P/F/M-code
1	System floor(first)	P
2	Pressure layer (first floor)	M
3	Wall(dwelling separating) 1	M
4	Wall(dwelling separating) 2	M
5	Wide slab storey floor	P
6	Pressure layer storey floor	M
7	Prefab inner cavity wall	P
8	Outer cavity wall	F
9	Lintel 1	P
10	Lintel 2	P
11	Window sill stone 1	F
12	Window sill stone 2	F
13	Glass 1	P
14	Glass 2	P
15	Door	P
16	Floor finishing (first floor)	M

Now the relations may be ordered in different ways. In relation diagram 1 the building parts have been ordered in such a way, that the building part with the largest number of relations is on top, the one with the lowest at the bottom. This indicates the most critical part. This diagram gives a first impression of the various dependencies; a good point of departure for further analysis.

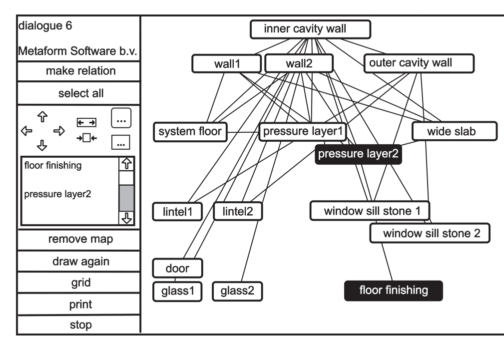
Relation diagram 2 classifies the building parts according to their P/F/M quality. It shows all P-P relations. If long chains of Part – Part relations are occurring, this is sign of many prefabricated building parts, all of them with a dependency relation. Any change has consequences for all other building parts, since the change can not be transferred to any other part. If the chain would be interrupted regularly with building parts with a Form- or Material quality, the ripple effect would be restricted significantly.

Relation diagram 3 shows a hierarchical ordering: the same relations, now in clusters of connection. It demonstrates that the critical component forms the connection between two clusters, displaying per cluster just internal relations. Spotting these clusters may indicate independent product development. It could also be a reason for adjustment of the architectural design, in order to lower the number of connections of one cluster with the critical component; for instance from three dependencies to one. It will simplify co-ordination during execution. On top of that, it is an indication for simple replacement in the future. In the context it should be remarked that complicated relations restrict flexibility, while straight relations are not proving the opposite automatically. When the relation, for instance, is one of gravity, like in 'floor resting on foundation', this is an indication for the foundation as a subject for independent product development. This also means that during the design stage it is possible to change the foundation principle. It does not mean that the foundation may be readily changed by a different one following the transfer of the building to its owner.

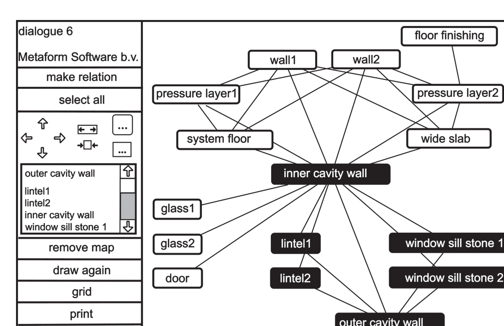
Analysing dependencies is an important tool for assuring the flexibility called for: during the design, execution, as well as usage stage of a building. If we see a building as a system, a co-operating whole, then the building node analysis is evoking the image of a building to be put together from various sub-systems, with a large amount of independence.



370 Relation diagram 1



371 Relation diagram 2



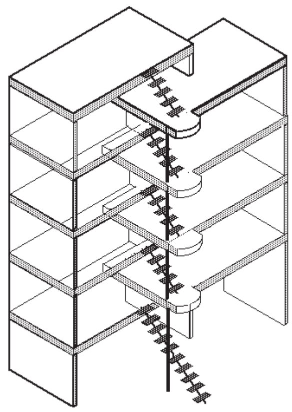
372 Relation diagram 3

38.15 CLASSIFICATION AS TO PRODUCTION

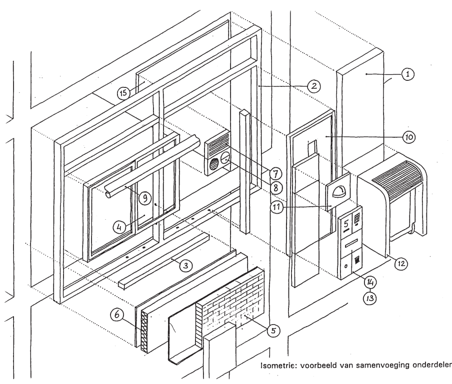
The dependency diagrams allow us to study and analyse the complexity of the connection of the parts. It is giving indications for clusters of components that may be developed as independent sub-systems, like carrying construction, façade, roof and interior facilities. This emancipation follows building practice, in which total sub-systems are pre-fabricated by a provider and applied in the works, with separate financial and guarantee arrangements.

Next, within each sub-system a further sub-division can be made of fixed and variable elements, between frames and substitutes. In this way a roof panel may become a frame for a sequence of roof windows, extensions and ducts. Frame and substitutes are classifications of component ordering; possibly co-inciding with carrier and facilities, classifications of decision forming. The consumer buys or rents a home with a standard roof, but an extension to it of his personal choice.

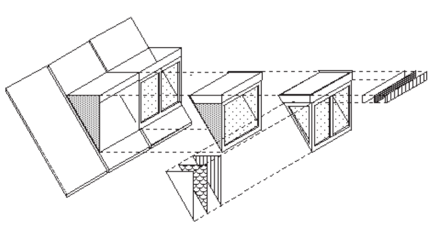
a Kapteijns, J.H.M. (1997) *Systematische productontwikkeling voor de bouw*.



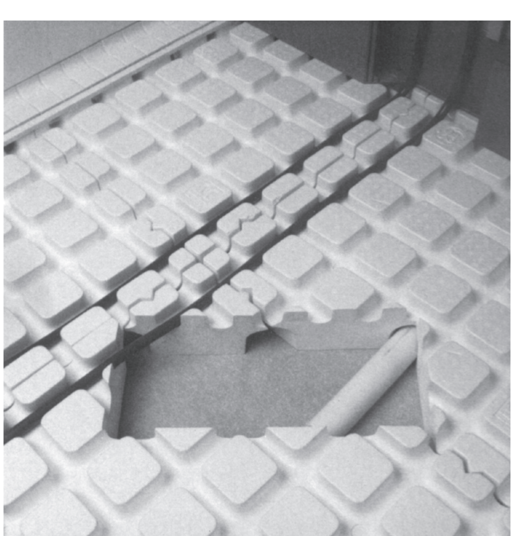
373 Skeleton



374 Optional window



375 Roof extension



376 Matura system

Carrying structure

The carrying structure is the sub-system of the building maximally connected to the location. Residential building in The Netherlands is mainly made of concrete, blocks of limestone and brick. The nature of these materials sees to it that larger size tolerances can be reckoned with than for other sub-systems. In addition the carrying construction provides the context, the 'frame' for the other sub-systems.

Façade

The façade has always been an sub-system, for which components (posts, windows, doors, bow-windows) were made in the carpenters' shop, then carried to the site, ready to install. Within the sub-system frame a substitution may be distinguished. The substitutions may be of an architectural nature, like windows and doors, but also constructional, like motorised shading, shutters, mailboxes, electric doorbells with inter-com and security cameras.

Roof

The laying of roofs has always been a separate profession. Roofs of thatch, slate, tiles and flat roof were provided by specialised sub-contractors. With the introduction of more extensive roof panels – the hinged roof being the largest among them – the manufacturing and applying of the sub-package is sub-contracted increasingly more often to suppliers. The roof is the framework for substitutes like windows, lighting surfaces, roof extensions and ducts for chimneys and ventilation.

Appliances

Appliances demonstrate the largest number of sub-contractors: plasterers, painters, tiling, plumbers, electricians. The main contractor always had an important co-ordinating task in this. The situation is slowly changing. Kitchen equipment, for instance, has vanished completed from building package and is sold now directly to consumers in the kitchen business, installing its wares without any interference from the main contractor. Appliances for bathrooms are being installed increasingly less often by traditional building partners; but ever more by specialists, approaching consumers directly. There is a clear trend that the whole area of appliances is becoming a constructional sub-system, installed by one agent in the glazed residence, without the interference of the contractor, and with bills directly charged to the consumer.

The building node study demonstrated that the building part groups mentioned allow independence towards sub-systems. That this trend can already be discerned in building is not the consequence of the building node study, but of mutual competition, the economic necessity to make a profit and of study following it.

The building industry finds itself on the eve of vast change. The residential shortage following WW II has been solved, the consumer has options as well as money. This means that the residential market is not determined any more by supply, but by demand. The consumer has power to buy; the building industry focusing on this has the best chance to make a profit and to survive. Building with frames, substitutes and independent sub-systems may provide an answer. In addition it is an important condition for independent development of building products; presently so advanced, that they cannot be developed any more for individual projects.

Lengthening the life-span of buildings, dis-assembly for renewed use and ultimately separate processing for waste are three other reasons for building with sub-systems.

Building node study is necessary, since it is not focusing primarily on improvement of the position of the building partners, but on flexibility of the building; finally on the built environment. The building industry understanding that is changing its bearings and will prevail.