5 Diversifying structure

5.1 Structure

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

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

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

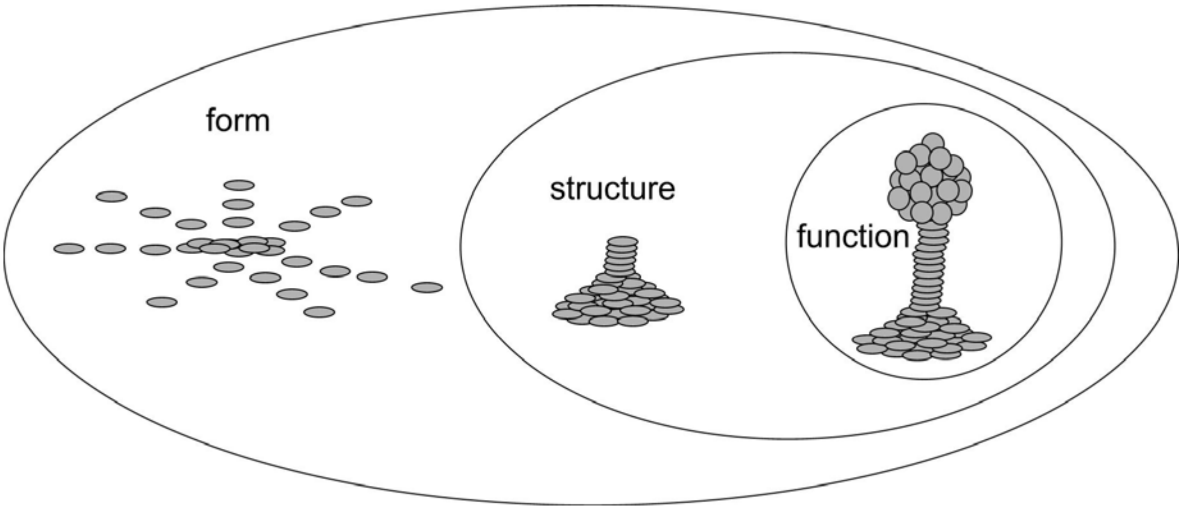

Fig. 126 The sequence of form, structure, function in the development of Dictyostelium discoideum R = 100 μm (the approximately 100 000 cells are depicted too large)

The evolutionary process from singular cells into an organism is currently repeated in the epigenesis of the slime mould Dictyostelium discoideum. It shows a process of concentration, structuring and functioning in a conditional sequence. This sequence, however, is not necessarily the sequence of design.

Variable coherence

Biological connections and separations may be more 'elastic' than human buildings. They move a little with their mobile, fluid or flowing environment, but they remain coherent. From temporary deformations, they mainly come back into their original form (resilience). Biological structures show less differences between stable and mobile parts than buildings. Moreover, they may show a gradual transition in space between more and less degrees of freedom, and less and more coherence (see *Fig. 127*). For example, mucous membranes show a transition from coherent into free movement through secreted mucus; sticky, thick fluid trapping pathogens.

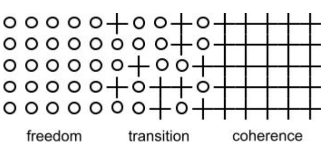

Fig. 127 Variable coherence

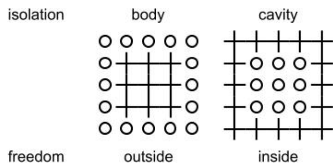

Fig. 128 Isolation

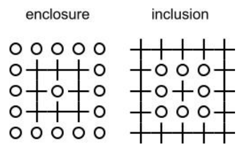

Fig. 129 Enclosure

A radially symmetric sequence of coherence may isolate bodies or cavities (see *Fig. 128*). Repeating this sequence may produce enclosures and inclusions (see *Fig. 129*).

Static and dynamic connections and separations

The terms 'connection' and 'separation' are ambiguous (see *Fig. 71* on page 105, repeated below). A wall separates in a different way than a column. A tube and a rope (or a stress resisting cable or stave) connect differently. In dynamics (see *Fig. 130*) and statics (see *Fig. 131*), 'connection' (convergent arrows) and 'separation' (divergent arrows) obtain a different meaning.
Separation requires a kind of connection that is perpendicular to the direction of separation. The other way around, connection requires a kind of separation in perpendicular directions. I will refer to this phenomenon as the 'direction paradox' (see page 28). A wall separates in two directions, but the separation requires a simultaneous connection in other directions.

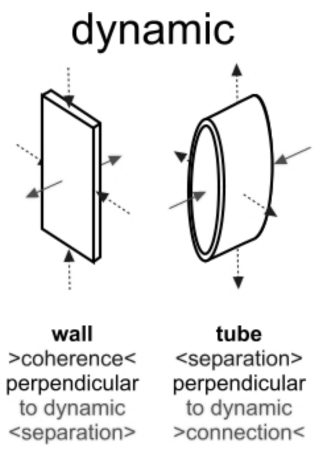

Fig. 130 Dynamic connection and separation

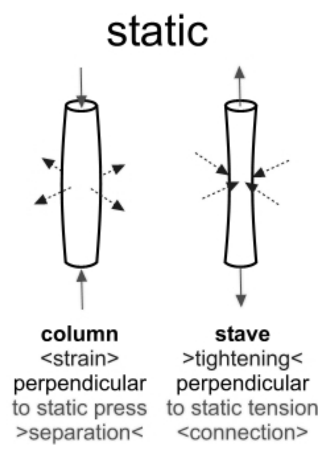

Fig. 131 Static separation and connection

Any operation (continuous arrow) requires secondary operations (dashed arrows) into the other directions. In *Fig. 130* and *Fig. 131*, the operation of the element (the resistance) is drawn, not the opposite (potential) movements it resists (which may be disturbing reading the images). A column resists the potential collapse of a floor, counteracting the force of its weight. Any operation resists movements or potential movements (forces) in some direction(s), in favour of movements in the other direction(s). In the gravity field on the Earth's surface, such operations may prevent natural, probable movements of vertical concentration (collapse) and horizontal de-concentration. Structure, thus, makes 'improbable' states of dispersion possible. Improbable possibilities are the core of design. Designers primarily draw connections and separations, even if they want to create possibilities in their counter-form.

Selectors and regulators

Devices that combine separation and connection in different directions, such as depicted in *Fig. 130* and *Fig. 131* , are selectors. They select the *directions* of resisted or allowed (potential) movement. The selectors of *Fig. 130* and *Fig. 131* are symmetrical in 3D, but there are also less symmetric selectors, such as a deck, a gutter or a bowl (see *Fig. 8* on page 29). What we have called 'enclosure' in the previous chapter, is essentially a bowl with a primarily radial symmetry. An urban square has the structure of a bowl. A street is a kind of gutter. The open land is a deck, leaving the highest degree of freedom at a gravity surface. If you accept time as a seventh possible direction, then a tap separates, but sometimes it connects if it is 'open'. Bridges, doors and transistors are essentially taps. If a tap regulates a flow between open and closed, you may call it a 'regulator', which may be a special kind of selector.

Conditional selectors

A tab is – in a more general sense – a 'conditional selector' (see *Fig. 9* on page 29). Its 'condition' is time. A sieve may select on size: open for small particles, but closed for large objects. Pedestrian or cycle paths may be closed for cars by stakes. Thus, the sieve is a conditional selector with size as its condition, but you may imagine other conditions for the selection by a sieve. For example, a cell membrane may be selected based on its chemical characteristics. A window is a sieve open for light, but if it can be opened for other movements, then it is also a tap. Legal regulations are concerned as non-physical, but their impact may be physical. They may operate as a tap or a sieve, structuring space and movement. Linguistic 'if…then'-constructions operate as a tap or a sieve. Zoning plans contain many of these conditional constructions, as a crucial legal part of their design.

Variable enclosures

The absolute value (zero point) of enclosure or seclusion as a variable may be total openness, because there is no absolute impenetrable ‘seclusion’. You always can add more isolating boundaries, but not always less. Isolation is relative. An enclosure may be separated by a semi-permeable or perforated wall. Thus, the perforations , such as windows and doors (sieves and taps), do not make the enclosure ‘more open’, but ‘less closed’.

Fig. 132 Enclosure from open into more closed

Eco-device

An enclosure combining walls, sieves and tabs is known as an ‘eco-device’[a] (see *Fig. 133*). An eco-device distinguishes two inward and two outward operations. The walls and sieves ‘resist’ inward movements or ‘retain’ outward movements. Openings, sieves or taps allow regulated ‘input’ and ‘output’. ‘Systems’ distinguish a boundary and an input and an output, but the concept of an eco-device makes designers aware of different operations of the boundary. A boundary is usually concerned with having symmetrical surfaces at both sides, but the opposite operations may require some asymmetry.

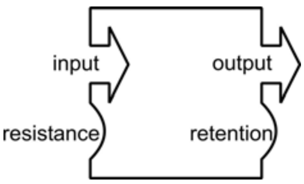

Fig. 133 Eco-device

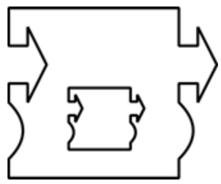

Fig. 134 Enclosing and enclosed eco-device

Different structures at different levels of scale

An enclosure may be embedded in a larger one (see *Fig. 134*). Then, it will operate differently with a different input, output, resistance and retention. At every separate level of scale, you may observe different impacts of connections and separations that select and regulate different processes. Outer structures ‘protect’ inner structures. From a radius of R = 30m onwards to the larger levels of scale, the impact of static connections and separations fades (see *Fig. 121* and *Fig. 122*). The vertical resistance against gravity, then, is dominated by the larger horizontal operations. At a larger level of scale, the selectors are mainly dynamic. Many selectors are visible as linear elements, such as landscape boundaries, waterways and roads. But, smaller differences of soil select plants, the availability of air and water selects species, the access of sunlight selects activities.

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[a] Leeuwen(1979)Ekologie I(Delft)THD 3429

A sequence of selective operations

If you go out, you will meet many selectors. You put your *coat* on; you leave your *house* through a *door*, *closing* its *lock* properly with a *key*; you put up an *umbrella* or you put on your *sunglasses* walking along your garden *path* into the *street*; you *unlock* and *open* your *car,* and so on. Any selector resists or mitigates the impact of natural phenomena of a larger scale, such as sun, wind, and water, potential threats, and distances that should be bridged. Moreover, there are many implicit selectors that protect you from silent threats, such as dikes, insurance, health care, and legal regulations, which may be executed by police or army, traffic lights and regulations. They must be included, or may be supposed, in any spatial design. The potential diversity of structure, however, is not as much elaborated and utilised in the human environment as you may observe in living systems, and less so in mechanical engineering[a].

[a] Rodenacker(1970) *Methodisches Konstruieren* (Berlin / Heidelberg / New York) Springer-Verlag

5.2 Polarities until 1km

Between ‘open’ and ‘closed’

The connections and separations introduced in the previous section are crucial in design. Their operations often result in a spatial polarity P, from ‘closed’ to ‘open’. Such polarities offer a global concept of ‘structure’, in order to be distinguished by a radius r, of their operation as P_r. At any level of scale you can observe locations that are open on one side and closed on the other side. *Fig. 117* on page 177 shows an embryo that is primarily developing a $P_{30\mu m}$ through gastrulation. *Fig. 126* on page 184 shows non-polarised cells developing a $P_{100\mu m}$, with a globe on top, opening to disperse its seeds. Plants, animals, humans, furniture (P_{1m}), rooms (P_{3m}), buildings (P_{10m}) and allotments (P_{30m}) show a back and a front that cannot be turned backwards or upside down without becoming inoperable. Architecture, urban and technical design innocently determine many polarities. If you use them to analyse the potentials of a location by drawing, and modify them into a global concept, then your very first ideas can be discussed. These drawings may serve as a starting point for further detailing your ideas into more specific connections, separations, selectors and regulators through design. You may diversify them further into new kinds of structures, at different levels of scale. This section aims to clarify existing polarities at any level of scale, and to make them operational for design.

The radius of polarisation

In a radius of R = 1m, you share a polarity (see *Fig. 135*) from back to front, with many animals. The openings of your eyes and nose are close to your mouth, which is also the input location of your gastrointestinal tract and the location of your taste. This polarity of your body suits the direction of your forward movement looking for food, opportunities, new experiences or danger. This primary polarity, then, integrates your sensoric and motoric operations.

Fig. 135 P_{1m}

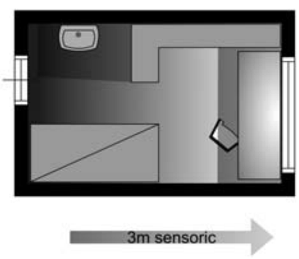

Fig. 136 P_{3m}(sensoric)

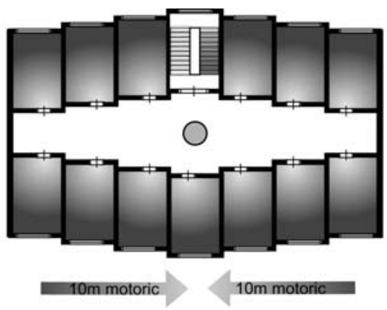

Fig. 137 P_{10m} (motoric)

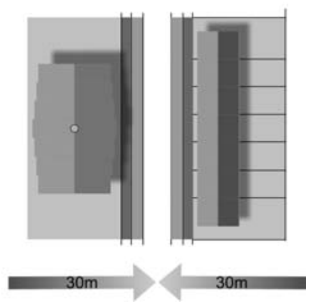

Fig. 138 P_{30m} (private-public)

A second top-down polarity is caused by your upright position as a human. This position may extend your visual horizon or, improve your auditive capacity. But, for urban, architectural and technical design, a horizontal front - back polarity is most important. Utensils such as books, computers and furniture have a back and a front (P_{30cm}). They cannot be turned around without losing their function.
A room is polarised into a window, which is open to sensoric impressions (see *Fig. 136*). Habraken[a] has named the resulting open and more closed zones: α- and β-zones. There are, however, also polarisations into a door for motoric possibilities. The gradients of these polarisations diversify your opportunities to arrange your furniture and your activities. The decreasing visual seclusion (darkness) into a window is operational in a nominal radius R = 3m, but the decreasing motoric seclusion extends through the door, opening up the rest of the building in a larger radius R = 10m (see *Fig. 137*). Leaving a building may unveil the next

[a] Habraken(1985) *De dragers en de mensen. Het einde van de massawoningbouw* (Eindhoven) Stichting Architecten Research

polarity of its own front or back (P_{30m}), operational in a radius of R = 30m between 'private' and 'public' (see *Fig. 138*). The operation of any polarity changes by scale.

Orthopolarity

It is remarkable that these successive polarisations are often perpendicular to each other. The R = 30m polarity of *Fig. 138* is perpendicular to R = 10m of *Fig. 137*, and so on ('orthopolarity': $P_{30m} \perp P_{10m} \perp P_{3m} \perp P_{10m}$). The reason may be that orthopolarity offers more possibilities than parallel polarities. The corners of an orthopolar room (see *Fig. 139*) obtain different operational possibilities, and consequently, a different use.

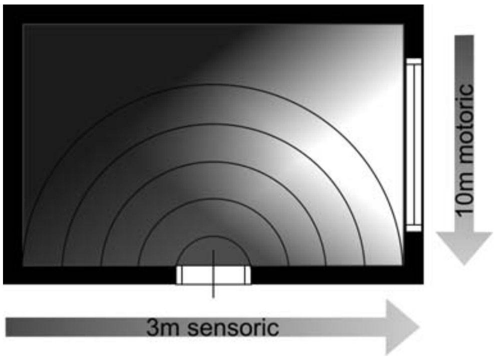

Fig. 139 Orthopolar R = 3m

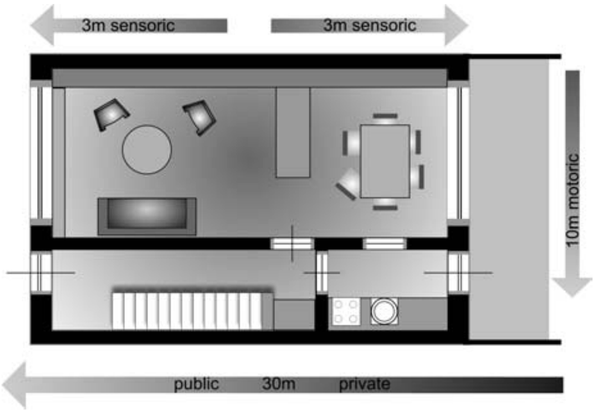

Fig. 140 Orthopolar R = 10m[a]

The room of *Fig. 136* has two different halves: a dark but accessible, and a light but less accessible one. Both polarities are in the same direction (synpolar). *Fig. 139* has four different corners. At this small surface, however, it may not produce more opportunities than the clear dual polarity into opposite directions of *Fig. 136*. The advantages may become even more operational in the radius R = 10m. The dwelling of *Fig. 140* shows 3 orthopolar polarities ($P_{3m} \perp P_{10m} \perp P_{30m}$), which makes different functions possible.
The motoric polarity of *Fig. 140* concentrates connections in a less closed section of the dwelling. The front~ and the back door, the staircase, the cables, pipes and taps for informatics, electricity, gas and water are separated from the less dynamic living and dining room. Architects may testify to their creativity if they propose a staircase or a kitchen in the living room, but it neglects a useful structural diversity.

[a] The '10m motoric' polarity in this figure is obviously shorter than 10m, but similar to the one of *Fig. 137*, and still fitting in the margins of 'nominal' size as explained in *Fig. 17* on page 52.

Synpolar and counterpolar

If you sit along the edge of a forest, (see *Fig. 141*) you will have a view with a backing. Your body, then, has the same polarity as your larger environment (synpolar).
It would feel unnatural to sit the other way around. It would be similar to your position if an old fashioned teacher put you in the corner of a classroom (counterpolar, see *Fig. 142*). Your open side, then, meets closed walls, and you do not know what happens behind your back.
If public banks are counterpolar, they offer a view of the road instead of the park.

Fig. 141 Synpolar

Fig. 142 Counterpolar

Fig. 143 Divergent (polarities of the same radius)

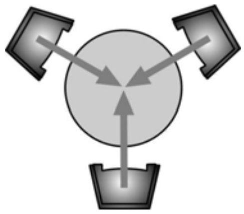

Fig. 144 Convergent

The location of the polarities are the same… …or different

Divergent and convergent polarities

You can recognise divergent structures in different ways: at the top of a hill, in order to obtain different views (see *Fig. 143*), sitting against a wall, standing back to back to protect each others' backs against attacks, or a panopticon, which is a prison that kept the prisoners in view by positioning all of them visually directed into one location of surveillance. A meeting at a table has a completely opposite *convergent* structure, (see *Fig. 144*) with different polarised locations. You may use your polarity to express your dissatisfaction by turning your chair.

Arrangements of polarities

Orthopolar, synpolar and counterpolar polarities combine polarities of a different radius. Divergent and convergent polarities share a similar radius (see *Fig. 145*).

Polarities	Name	#radiuses	#locations	#directions
Combinations of polarities at one location				
	synpolar	≥ 2	≥ 1	≥ 1
	counterpolar	≥ 2	≥ 1	≥ 2
	orthopolar	≥ 2	≥ 1	≥ 2
	divergent	≥ 1	≥ 1	≥ 2
Arrangements of polarities at different locations				
	convergent	≥ 1	≥ 2	≥ 2
	consecutive	≥ 1	≥ 2	≥ 1
	parallel	≥ 1	≥ 2	≥ 1
	counterparallel	≥ 1	≥ 2	≥ 1

Fig. 145 Kinds of polarities

If you look at the minimal number of *locations* (#locations) involved, then a divergent polarisation still can appear at one location (e.g. a hill-top), but convergence cannot. Convergent polarities require at least two polarised locations. *Fig. 137* and *Fig. 138* (opposite buildings directed into a street) already showed a special case of 'opposite' convergence, at a minimum of two different locations. This is no longer a *combination* at one location, but an '*arrangement*' of polarities at different locations. There may be many more arrangements, but it is of little use to give them all a separate name.

Consecutive and parallel polarities, symmetry

In the symmetric arrangements of *Fig. 146*, the open sides of the convergent polarities will meet each other at the street. The closed sides of the divergent polarities will meet each other at the back path. The divergent polarity this time counts more than one location (2). You may, however, raise the back path to obtain 1 'hill top' location.

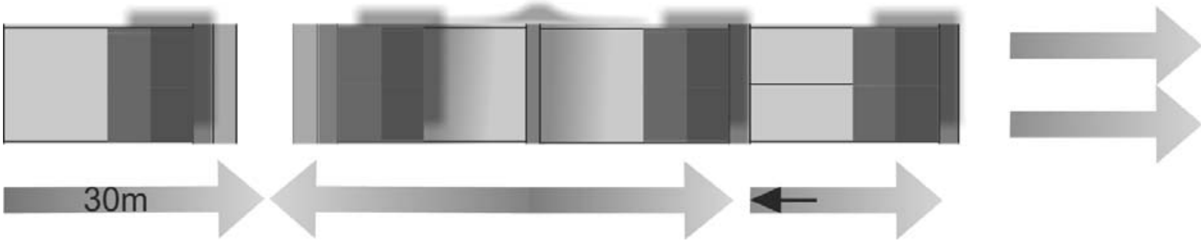

Fig. 146 Opposite convergent, divergent *Fig. 147 Consecutive* *Fig. 148 Parallel*

The open side of the first consecutive polarity in *Fig. 147* meets the closed side of the second, causing a counterpolarity. It decreases the radius of the P_{30m}. Your garden and your sleeping rooms become a public area for your rear neighbour, if you do not close your curtains and build a high fence in your backyard. The fence would, however, destroy the P_{30m} of your rear neighbour. Symmetry may have advantages.

Strengthening weakened polarities

Parallel directions (see *Fig. 148*) do not disturb polarities; counterparallel ones may disturb polarities. Compensations, however, may increase the structural diversity. The counterparallel arrangement of *Fig. 149* has gardens enclosed by side façades, but they are open to the roads. It is compensated by added separations and connections. A sloped garden climbs against a rear wall. The access to the street (used as a back path) is limited to a gate, which is accessible by an excavated path, which is hidden under trees. The lower (more closed) back façades face a visually elongated garden. A separating ditch (catching the water of the sloped gardens and the long roofs) separates the garden even more. It may be extended into a pond. The street fronts show the diversity of high, but open, façades, alternating with closed but lower walls with gates, trees and sunlight on the street. Compensation may diversify.

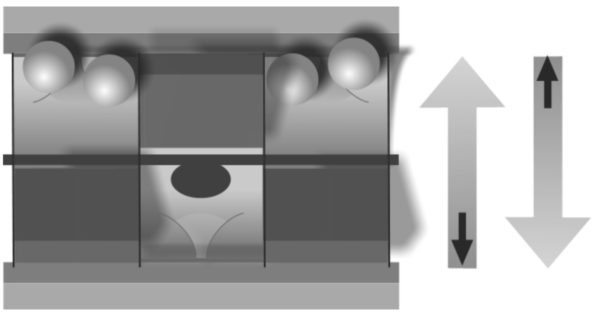

Fig. 149 Compensated counterparallel P_{30m}

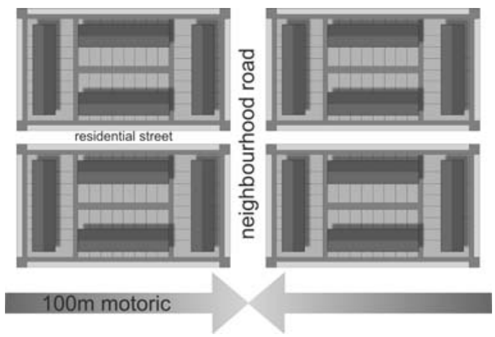

Fig. 150 polarities(P_{100m}(residential street))

Motoric polarities of roads

Residential streets open into crossings with equal or wider roads (see *Fig. 150*), producing a P_{100m};, neighbourhood roads do the same producing a P_{300m} (see *Fig. 151*), and so on. These polarities are stronger crossing a wider road and meeting a larger building height (see *Fig. 152*), but any polarity itself can be strengthened. If a street is 'open' (α) into a crossing, then there is also a 'closed' (β) area inside. You may design a narrow α and a wider β , in order to obtain more 'enclosure' (structure). You, then, can add more difference in parking, plantation, street furniture, lightning and architecture (content and form).

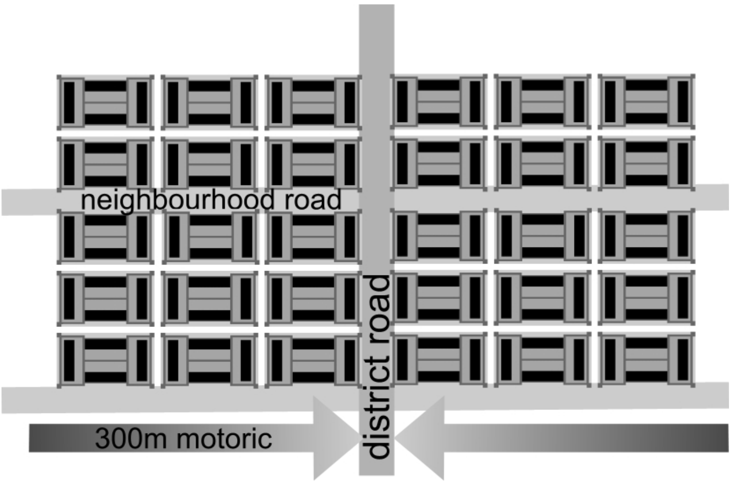

Fig. 151 P_{300m} of a neighbourhood road

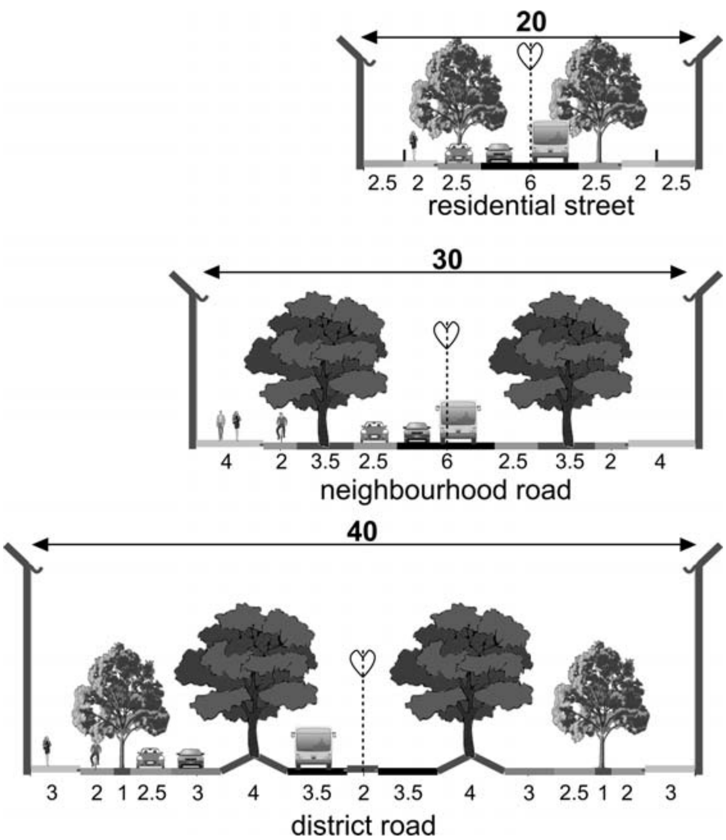

Fig. 152 R=30m Profiles of streets and roads

Sensoric and motoric district polarities

In any urban area filled with buildings and roads appear less closed, less directed and less regulated spaces, such as squares and parks with easy public access. The mere existence of some emptiness may be more important to avoid a kind of urban claustrophobia, than their actual use. They serve your orientation in the urban landscape. Green areas provide an alternative for the usual agenda of urban life through other kinds of life ,without an agenda. If you make green areas accessible at an average walking distance equal to their size expressed in a radius r ('Standard Green Structure', see *Fig. 109* on page 170), then a neighbourhood park r = 100m in every neighbourhood R = 300m (requiring an average walking distance of 100m) will take approximately 10% of the urban surface. A district park r=300m with an average walking distance of 300m will also take approximately 10%, and so on (see *Fig. 153*). *Fig. 153* is a theoretical district R= 1km, approaching the concept of a Standard green structure. It counts 12 residential neighbourhoods at R = 300m, which are arranged around a district centre, which is surrounded by a district road. The standard building groups (see *Fig. 150* on page 191) turn their front into this road. The convergent district roads give access to the centre with a view to the central park.
The 12 neighbourhoods are synpolar to the centre, by parks with a primary school and other local facilities at open squares. The synpolarity, then, contains a motoric district P_{1000m}, a sensoric neighbourhood P_{300m} and a park-square P_{100m}. Some T- crossings offer a focal α point (a building or a park), in order to strengthen a motoric local street P_{100m}.

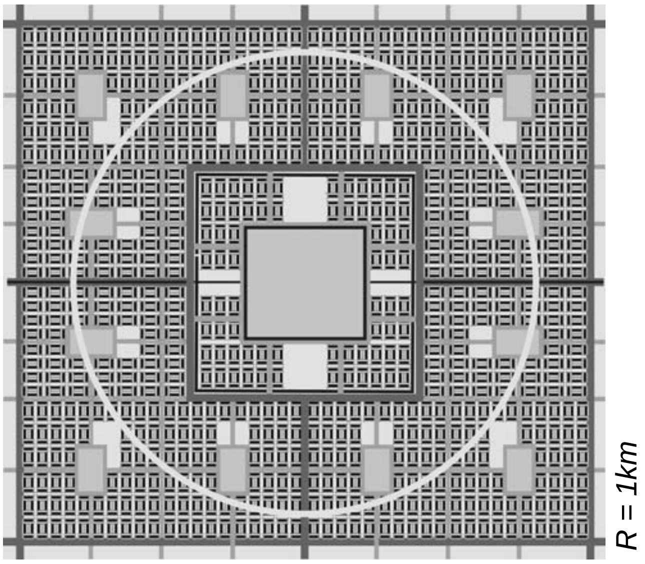

Fig. 153 Dwellings, roads, parks and facilities

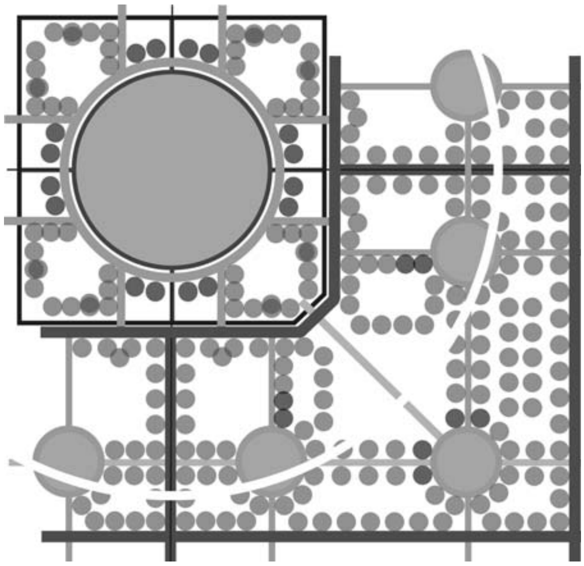

Fig. 154 Redistributing floor space

Strengthening polarities through form

Fig. 154 reduces a quarter of *Fig. 153* into equal floor space by dots r = 30m (representing 3000m^2 floor space or 100 inhabitants). Its redistribution suggests the intended urban concept better by varying densities. This more abstract representation can be discussed and easily changed by replacing dots. It may serve as a 'distributed programme' for architectural detailing. You may allow yourself to interpret a dot within a radius of 100m (dot tolerance). You may assign a designer for detailing a number of coherent dots and adjacent public space, such as two β sides of a street. Any R = 30m dot may be divided into 10 dots (dot division), r = 10m representing 300m^2 floor space; any R = 10m dot into 10 dots r = 3m, and so on, to reach the final stage of detailing.

5.3 Structure without polarities

A third order variable

Values of decreasing seclusion in a spatial sequence (‘polarity’) are realised by values of primary variables, such as the light in a room, temperature in a house, built-up area in a neighbourhood. You cannot realise any ‘openness’ or ‘seclusion’ without these primary variables. Polarity, thus, is a ‘second order’ variable, or even better (if you accept ‘Form’ as ‘second order’ variable): a variable of a ‘third order’. It structures primary variables and their form. From many variables, you can classify their extremes as ‘open’ or ‘closed’. Adding more content may strengthen the polarity. For example, differences of temperature, humidity and rules of behaviour usually accompany the polarity$_{10m,}$ between a living room and a hallway (see *Fig. 140*). You may add even more differences to strengthen this polarity (colour, texture or upholstery). In this section, I will study which variables of *Fig. 74* on page 114 are ‘polarised’ themselves, and which are not (see page 196 and 197). Before doing so, I have to determine if single or combined variables may show a kind of structure themselves, not covered by any polarity.

Ranked values

An environmental variable (see the list of *Fig. 74* on page 114) may develop its own successive values as a gradient in space, without any polarity of seclusion.
For example, the sequence of rock-gravel-sand-silt-clay in the deposits of a former river is a sequence of ranked particle size, without a beginning or an end, to be classified as ‘open’ or ‘closed’. It is *sorted* by some selective polar process in the past, but is it presently *structure*? Does ‘structure’ (seen its general definition on page 183) also include the set of ‘connections’ and ‘separations’ between the values that are ranked in a variable? I would call it ‘ranking instead of structure (see *Fig. 155*). These ‘connections and separations’ do not stabilise a form. The values are not actually separated and connected, but *distinguished* and *ranked* in a variable as a human concept. The natural sequence of rock-gravel-sand-silt-clay in the deposits of a river is stabilised by the surface of the Earth and its gravity, not by human distinction and ordering. What we observe is a gradually changing *texture*, not a stabilising underlying *structure*. If you use the clay to connect separating pieces of rock with some support of gravity into masonry, then you may obtain ‘structura’ (´brickwork´ in Latin). In that case, it may lose any ranked order (see *Fig. 156*).

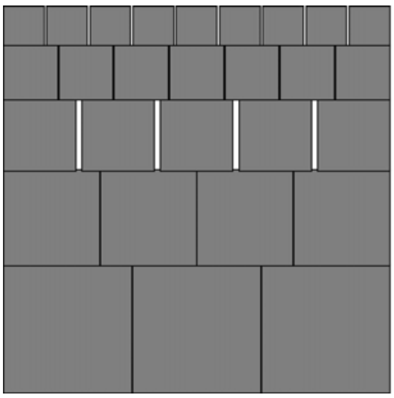

Fig. 155 Ranked order

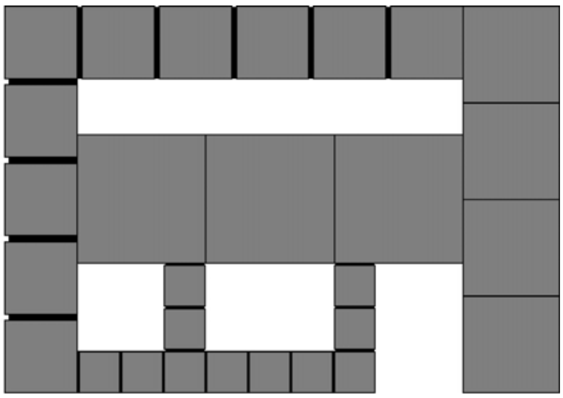

Fig. 156 Structured order

Moreover, Fig. 156 shows that structure supposes form, which is a distribution of values in space. You may recognise regularities (patterns) and a composition, but ‘structure’ is something else. It is the set of stabilising separations and connections.

Relations between variables

If two variables develop their values parallel in space, then their values become related in a unique combination, at any location in their sequence (see *Fig. 157*).

Fig. 157 Negative and positive ranked spatial relations between two variables.

You may conceptualise the mutual relation of variables in a formula with values connected by mathematical operators (+, −, *, /, and so on). The formula with *separated* values *connected* by operators may have a ‘structure’, which stabilises its results. Does a reality, however, have the same connections and separations as its simulation, even if the result looks equal? Is its form stabilised by the same (adding, subtracting, multiplying, dividing and so on) operations? A formula or a set of related formulas (a model) is a *procedure*, a sequence in time, an algorithm. It eventually results in a similar pattern if you follow its strict sequence of operations. The same pattern, however, may come into being in many different ways. Moreover, there are many forms and designs that still cannot be simulated or distinguished by mathematical operations, if they do not show sufficient repetition or ordinal sequences to be named as variables (see *Fig. 158*).

Fig. 158 Unranked spatial relations of values in Fig. 157

Mathematical models suppose equality

A mathematical model may be useful for prediction or design, but the results of its equations is still not the diverse reality you may observe, or the possibility you want to design. For example, suppose that you observe a soil somewhere, where the distance (d) from the first stone into the successive gravel, sand, silt and clay appears to be inversely proportional to their particle size (s): $d=a/s$. Suppose, that you have observed elsewhere, that the size of the deposited particles (s) is proportional to the average velocity (v) of the water transporting them, $s=b*v$. You, then, may conclude that once there must have been a stream that left the gravel, sand, silt and clay at their successive locations. This model, however, simulates a *process*, that apparently once came to an end by other variables (local geomorphology, geologic movements, climate, human artifacts), stabilising the state of dispersion observed, but not its actual ‘structure’.

Stabilising procedures

Stabilising processes can be simulated by optimisation procedures, which are mainly based on matrix calculus.[a] Contemporary geometry has the same basis.[b] A matrix is a table with cells filled with values or formulas for different local states or processes. If the locations in the table refer to the locations of a real surface, then the matrix is a map, simulating different values and processes at every location. If adjacent locations counteract, then the processes may stabilise each other, producing an equilibrium in the direction of their adjacency. For example, *Fig. 159* shows a map with randomly sloped cells. If the rain falls at that surface, then they determine the course of runoff streams, as simulated in *Fig. 160*.

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[a] Lay(2000) *Linear Algebra and its Applications.* (Boston / San Francisco / New York / London) Addison-Wesley
[b] Aarts(2000) Meetkunde. Facetten van de planimetrie en stereometrie (Utrecht) Epsilon Uitgaven

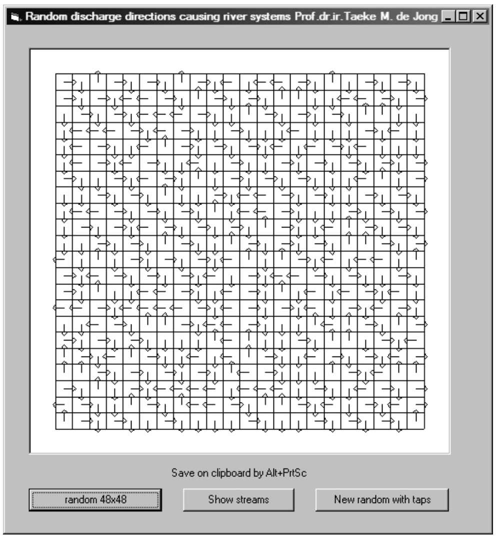

Fig. 159 Directions of slopes

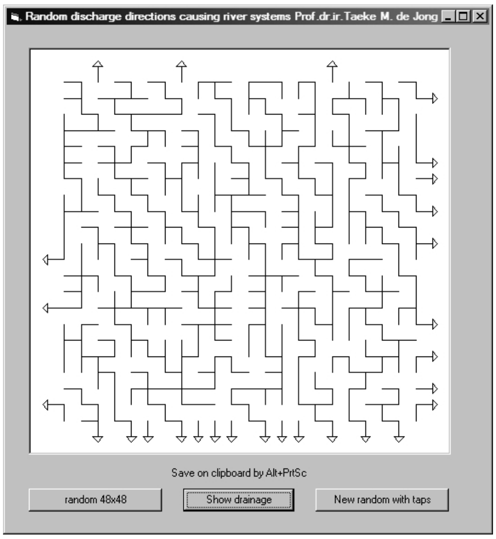

Fig. 160 Resulting course of streams[a]

Fig. 160 shows connections and separations (watersheds) that you know from reality. Optimising models, then, may simulate structures. Moreover, the streams show closed (source) and open (destination) sides: polarities. Is that always the case? Does stabilising symmetric counteractions of values or (potential) processes always produce a polarity in some direction? Let us first investigate whether the variables in *Fig. 74* on page 114 already show a kind of polarity themselves, before they may cooperate with some existent polarity, or neutralise it through counterpolarity. Then, we may answer the question whether there are other variables or structures *without* a relation to successive degrees of seclusion.

Polarised variables

The extreme values of many variables in *Fig. 74* on page 114 immediately remind one of some openness or seclusion. Let me follow the alphabetical sequence of the list. The Access values at different levels of scale are obviously liable to motoric openness and seclusion. Agriculture$_{3km}$, however, ranging between fields and settlements, raises a dilemma. If you speak about ‘the open field’, then the sensoric connection seems obvious, but in a motoric sense, a settlement may be ‘open’. It may serve as a gate to the market, or to a larger society. You may conclude that there is a relation anyhow, but in one or the other way. Allotment$_{100m}$ ranging from detached until attached is no problem, but Altitude$_{30m}$? Is ‘high’ less closed than ‘low’? You may also draw the conclusion that there is a relation, but both ways. Altitude$_{100km}$, however, ranging from lowlands into highlands may be associated with the openness of lowlands and the seclusion of mountainous areas with their valleys. The horizontal or vertical architectural Articulation$_{30m}$ again raises a dilemma. Is ‘vertical’ more ‘closed’? If you remind the many horizontal galleries of flats, then you may indeed associate them with ‘openness’. The difference in architecture, as referred to in the paragraph Motoric polarities on page 192, however, may be elaborated as a more vertical articulation at the α corners of the street, and a more horizontal articulation in the inner β zone. If it is related to the higher Altitude$_{30m}$ of buildings at the corners, since higher buildings offer more possibilities for vertical articulation than lower buildings, then it may lead to the conclusion that there is a relation. However that may be, you also may elaborate on it conversely: a vertical articulation in the β zone and a horizontal one in the α zone. Since both are possible, you may conclude that it is the first independent variable of the list. You can relate it to a polarity any way you want. In any case, however, it will strengthen the polarity, simply because it adds a difference between α and β.

[a] http://team.bk.tudelft.nl/Publications/XLS/Rivers(Drainage).exe
http://team.bk.tudelft.nl/Publications/XLS/Rivers(Drainage).zip

Fact, association or possibility

You may argue, that the dependencies concluded above are no more than associations without empirical evidence. That is true, but designers are not assigned to discover truths or probabilities by empirical research. Their task is to invent improbable possibilities. *Possibilities* only may become *true* through realisation. It changes the argument into what is more or less *possible*. In that field of study, you are forced to estimate beforehand instead of measuring afterwards. The estimation that accessible or detached houses should be associated with openness (inaccessible or attached houses with seclusion) is difficult to deny. The question whether there are independent variables in the list, comes down to the question whether a designer could easily deny (and change) a relation of a variable with a sequence of seclusion (including the cases where that relation to the sequence is ambiguous). In other words: are these values useful as legend units in a drawing, without any reference to a sequence of seclusion?

Variables without polarity

A relation of $\text{Articulation}_{30m}$, with some degree of seclusion, could easily be denied through design. The next variable is Boundary Richness_{10m}, , which ranges between sharp and vague boundaries. It is an ecological term[a] that is mainly associated with transitions in the soil between more homogeneous (e.g. wet and dry) areas. In the gradient of a vague boundary (e.g. with all degrees of humidity), more organisms can find their optimal niche than on the more homogeneous biotopes at both sides. They are separated by a sharp boundary. Biotopes are characterised by many variables. At least one variable substantially changes its values at their mutual boundary. Boundary richness determines the number of intermediate values between its extremes. This is not necessarily related to a sequence of seclusion. Boundary Richness is relevant for design. It can be applied to any variable. It is then at least a second order variable of form, as it distinguishes between vague and sharp forms. If a boundary actually separates both sides, thereby stabilising their difference, then it would be a third order variable of structure. I would, however, call such a boundary a 'border'.
Colour_{1m} seems independent. You can paint colours without any reference to 'open' or 'closed'. But I doubt it. You may associate dark colours with 'closed' and white with 'open'. Geology_{10km} or History_{1km} are not only independent from a sequence of seclusion, they are even autonomous. They are relevant for design (you can utilise them), but you cannot change them through design, other than to destroy their values.
The other variables that are not necessarily liable to a sequence of seclusion are Ecology_{3km}, Life_{1m}, Light_{1m}, Humidity_{3m}, Nature_{30km}, Relief_{100m}, Size_{1m}, Sunlight_{30m}, Surface_{1m}, Technology_{3km}, $\text{Technology}_{100km}$, Temperature_{1m}, Temperature_{3m}.
That limited number of independent variables may vary *in nature* without causing any degree of seclusion, but you cannot vary their values *through design*, without applying some kind of solid material leaving space for their variation. This again implies a polarity at the lowest level of solid matter and adjacent space. But at the larger levels of scale, there still may be structures without polarity.

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[a] Leeuwen(1965) *Over grenzen en grensmilieu's* **IN** *Jaarboek 1964 Koninklijke Nederlandse Botanische Vereniging* p53-54
Leeuwen(1973) *Ekologie* (Delft) TH-Delft, Afd. Bouwkunde 3412b, Vakgroep Landschapskunde en Ekologie Hb 20 A
http://team.bk.tudelft.nl/Publications/2005/Leeuwen/Leeuwen(1973)Ekologie(Delft)THD%203412b.pdf
Leeuwen(1979) *Ekologie I* (Delft) THD 3429
Leeuwen(1980) *Ekologie II*. (Delft) THD 3416
Westhoff;Bakker;Leeuwen;Voo(1970) *Wilde Planten - Deel 1. Algemene inleiding, duinen en zilte gronden.* ('s-Gravenland) Vereniging tot behoud van natuurmonumenten in Nederland p164-169

Structures without polarity

The question in the beginning of this section was, whether there is a kind of 'structure' independent from any sequence of seclusion. The independent variables summarised above may be related through design into a structure without such a polarity. A straight wall in the open field does not have to enclose anything to be a structure stabilising different values of any independent variable at both sides of the wall. It may be used to grow grapes at the sunny side, generating shadows on the other side, even without enclosing a garden. Access of sunlight is related with temperature, humidity or conditions of life. In that case, however, the locations at both sides are still more and less 'closed' to sunlight. A screen may protect you against the wind without enclosing anything, but it still has sides more and less 'closed' from the wind. Both polarities may be counterpolar. Because the sunlight and the wind are vector fields with changing and even different directions, separations and connections will not make them as stable as an enclosure in any direction would. You may conclude that non-enclosing structures offer less 'structure' than enclosed ones. It is even more the case with non-vector variables, such as humidity, temperature or other conditions for life. They are dispersed in any direction if they are not regulated by vector fields of sun, wind, rain or runoff. In nature, you may find many 'weak' (non-enclosing) structures, which stabilise differences in one direction. In the other directions, distance may play a role as an enclosing separation. Design, however, mainly reduces these distances through separations, and bridges them through connections. Distance may be used as a separating factor in environmental zoning around industries and installations, in order to reduce nuisances. But, even then, design may look for material source-directed separations, in order to save space. In mechanical engineering, non-enclosing structures may play a role (jet-propulsion, military devices such as defence walls or guns), but in spatial design and biology, degrees of seclusion play a prominent role. In the next section, I will neglect these 'weak' polarities, and limit myself to structures that are dependent from some sequence of seclusion.

5.4 Polarities larger than 1km

Lessons from the smaller polarities

Section 5.2 described different polarities operational until 1km :

P_{1m}: front and back of people, furniture and utensils;
P_{3m}: window-side and inner part of a room;
P_{10m}: direct accessible and less accessible parts in a building;
P_{30m}: public areas in front of buildings and private backyards;
P_{100m}: crossings, access parts and inner parts of streets, courts, cul-de-sacs;
P_{300m}: green, paved, built-up, nature and culture in neighbourhoods;
P_{1km}: residential and central parts of a district.

The difference between visual and actual access resulted in a distinction between sensoric and motoric polarities. At some levels of scale (R = 3, 30, 300m), the sensoric polarities seemed to be dominant; the motoric polarities dominated at the other levels (R = 10, 100, 100m). Different cooperating or counteracting polarities appeared to be possible at the same location. Polarities at different locations showed arrangements of cooperating or counteracting polarities that are so commonly known, that they could get their own name. Compensations of counteracting polarities appeared to be interesting from a viewpoint of environmental diversification. They diversified form and content at lower levels of scale. Polarities could be strengthened or weakened by adding variables. Many of these variables contain values that can be associated with openness or seclusion themselves (see page 196).

Grain and directions

Referring to the theoretical district of *Fig. 153* on page 193, *Fig. 161* shows the R = 1km part of this model more precise at the same scale as *Fig. 162*. Compared to the closed building blocks of the city of Amsterdam (see *Fig. 162*), the minimal grain r of the model is smaller than it is often found in reality. To visualise P_{1km} better and to make it manageable for design, *Fig. 154* on page 193 reduced it by dots r = 30m representing 3000m^2 floor space or 100 inhabitants. A lower resolution R/r makes a P_R more recognisable.

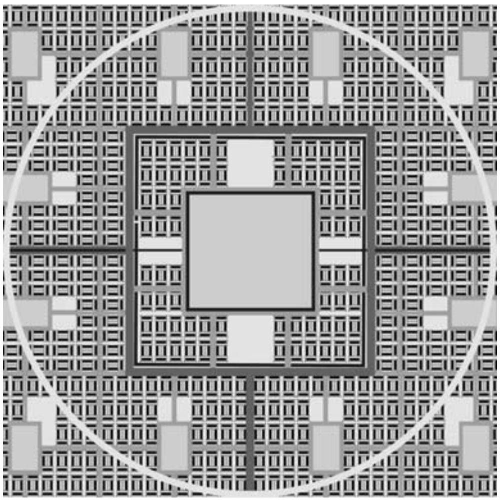

Fig. 161 R = 1km frame, r = 10m grain

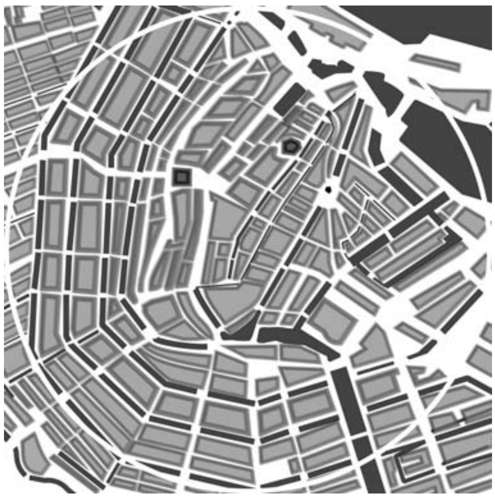

Fig. 162 Amsterdam city R = 1km, r = 30m

The diversity of sizes and directions of *Fig. 162* diversifies the polarities mutually through their form. The copy-paste regularity of *Fig. 161* can be diversified only by content and function. Counting the number of street corners and angles passed from a location to reach any other location is an indication of its ‘connectivity’ or centrality, known as Space Syntax developed by Hillier[a]. Calculated from the most connected location, you then have to pass a minimum of turns into any other location. Minimising them reduces the resistance of customers to go shopping.

Fig. 163 R=3km detail of Fig. 98 and Space Syntax analyses[b] at 2 levels of the same area

The minimal diversity of sizes and directions of *Fig. 161* however, minimises the number of street corners for any location. Space Syntax, then, only diversifies in ‘deformed grids’. Compared to connectivity values of a totally regular grid, it may offer a degree of morphological diversity, or ‘structural complexity’, which determines its motoric resistance .The motoric P_{3km} that is described below is similar to the previous motoric P_{1km} described on page 193, but P_{10km} again may appear to be sensoric.

Polarities of towns and conurbations

The motoric polarities P_{3km} from the periphery of a town into its centre produce a very common convergent arrangement (see *Fig. 164*). It is experienced along the main roads into the central city inwards and outwards, accompanied by increasing or decreasing density and dynamics. You could, however, add more content.

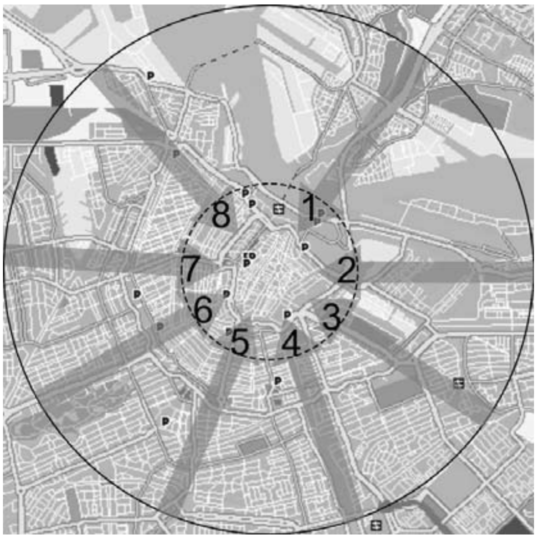

Fig. 164 Amsterdam motoric P_{3km} [c]

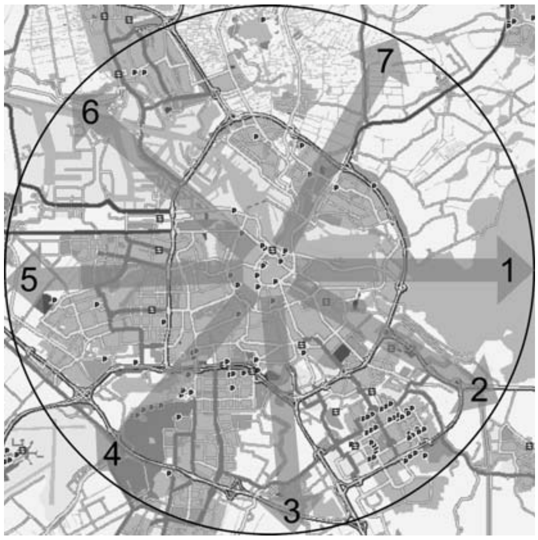

Fig. 165 Amsterdam sensoric P_{10km} [a]

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[a] Hillier(1999) Centrality as a process: accounting for attraction inequalities in deformed grids (Urban Design International,)4 3&4 p 107-127

[b] Map elaborated and Space Syntax analyses by Akkelies van Nes(2012)

[c] CityDisc(2000) Den Haag

You may add different variables for different polarities (1-8 in *Fig. 164*). Particularly the α and $\alpha\beta$ locations, where arterial roads connect to the central city or to an intermediate ring road, could be elaborated as urban squares that subsequently synpolarised themselves through parking, public transport stops, and gates into the city named as Northgate, Eastgate and so on. Railway stations, such as the Gare du Nord in Paris, are synpolarised at an even smaller scale, offering a strong urban orientation.
The sensoric polarities P_{10km} into the landscapes surrounding a conurbation produce a divergent arrangement (see *Fig. 165*). Their diversity is dominated by the landscapes and the large parks, which eventually serve as their forerunners. Many ecological variables, such as tree species characterising roads, parks and districts, are available to strengthen them. Amsterdam has a rich R = 10km structural diversification, e.g. compared to Rotterdam. The 7 polarities of *Fig. 165* refer to a great diversity of surrounding landscapes:

1 The great lake IJsselmeer, the former access to the sea and its colonies
2 The sandy Gooi landscape with expensive residential villages
3 The river Amstel and the peat lake area surrounding its course
4 The open polder area of the Haarlemmermeer with its airport Schiphol
5 The area behind the coast until its sandy dunes
6 The harbour area
7 A peculiar polder landscape appropriately named ‘Waterland’

Outside the urban area, 10km polarities (e.g. between forests and open areas) produce a structural diversity that is important for birds (and human recreation).

Regional polarities

Present conurbations mainly have been developed at the most accessible locations (rivers, roads and their crossings). The less accessible parts (mountains, moors) have been left for nature, agriculture, smaller towns and villages with smaller territories, in a landscape of convergent polarities around them (a Christaller hierarchy of central places[a]).

Fig. 166 Randstad motoric P_{30km} [b]

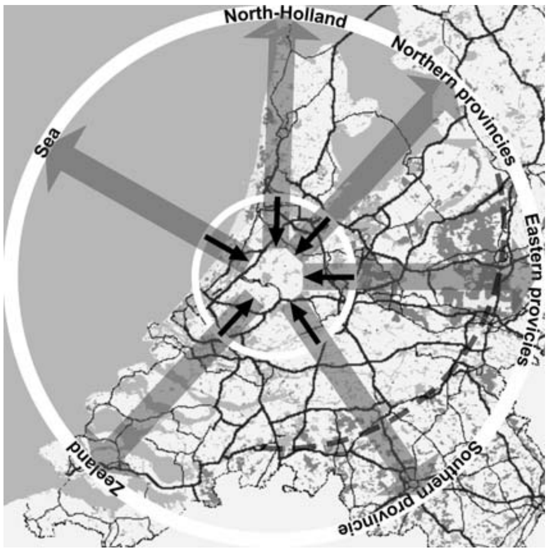

Fig. 167 Holland sensoric $P_{30, 100km}$ [c]

[a] Christaller(1933) Die zentralen Orte in Süddeutschland: eine ökonomisch-geografische Untersuchung über die Gesetzmässigkeit der Verbreitung und Entwicklung der Siedlungen mit städtischen Funktionen (Jena) G. Fischer
[b] CityDisc(2000) Den Haag

A regional symmetry

In the Netherlands, the old river Rhine flowed from Utrecht in the East into Leiden in the West through the extended moors of Holland drained into the North by the river Amstel and into the South by de river Rotte. The moors were probably used as hayland (in Dutch 'hooiland', probably a better origin for the name 'Holland' than the official one[a]).
At their East and West boundaries, the North-South traffic may have offered Utrecht and Leiden crucial intersections with the still existing Old Rhine (Oude Rijn).
The Old Rhine, however, was cut off in 1122 AD due to frequent flood events in Utrecht and Holland. The main course of the river Rhine was replaced Southwards. The dam on the river Rotte prevented floods from the Rhine in the Southern parts of Holland and the Rotte-dam (Rotterdam) became the final central place in the South, just as the Amstel-dam did in the North against the floods from the IJssel-lake.
This structure clarifies the remarkable symmetry of the Rotte and the Amstel draining Holland in opposite directions with large cities at their ends, perpendicular to the axis of the still existing river Old Rhine between Utrecht and Leiden. The central moors (Holland) became increaslingly occupied in diked polders, drained by wind mills, exploited for cattle, and its peat being excavated for fuel. By doing so, the water level in Holland subsided below the levels of the IJsselmeer and the Rhine, forcing to build more dikes and outlet canals. The Old Rhine became one of these canals, now flowing between dikes. The present 'open' Green Heart of the Randstad now shows a reverse convergent sensoric polarity, which is protected by law, and represented as counterpolar in *Fig. 167*.
The R = 30km Randstad enclosing its Green Heart is surrounded by less dense provinces, in a radius of R = 100km. Each direction shows a different kind of 'openness', resulting in a divergent sensoric polarity (see *Fig. 167*). The Eastern and Southern polarities, however, are crossed by a remarkable second ring of towns and conurbations, at 80km around Amsterdam. It may suggest emerging other polarisations that are weakening the Eastern and Southern polarities.

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[a] Veen(1990) Etymologisch woordenboek (Utrecht) Van Dale lexicografie

Continental and fluvial polarities

A continent is opened up into the sea by rivers. Highways and railways follow their course. You may call the polarities P_{1000km} , which are produced by such rivers, 'fluvial' polarities (see *Fig. 169*).

Fig. 168 $P_{continental, fluvial}$ and Rivers P_{300km}

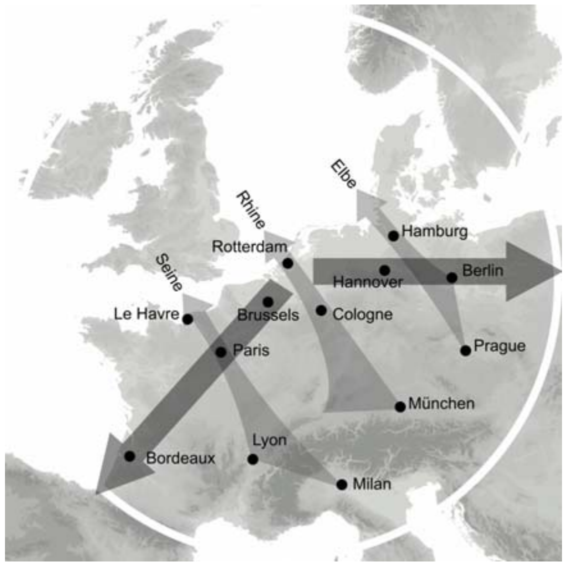

Fig. 169 Rivers P_{300km} crossed by P_{3000km}

Ways with a 'continental' (R = 3000km) reach cross them at some distance from the coast. The coastal routes from the Randstad into Eastern and Southern Europe, then, may be concerned to be part of a bipolar 'continental' P_{3000km}. In its North-West corner, the Amsterdam airport offers access from the sky, and Rotterdam harbour from the sea into this polarity.

The rivers Elbe, Rhine and Seine offer Berlin, Randstad and Paris a 'crucial' position, where they cross the main coastal routes. The other way around, the inland position of Paris and Berlin, determined the distance of the main roads to the coast. These conurbations require a region of R = >100km to surround them, in order to obtain a sufficient centrality for a capital status. This radius, then, requires a separate coastal harbour in their territory (Le Havre and Hamburg) to obtain an international status. At a similar distance, Rotterdam serves as the harbour of the 'Metropolregion Rhein-Ruhr' (Köln, Dortmund, Düsseldorf, Essen)) and the former German capital Bonn. Paris, Berlin and the Metropolregion Rhein-Ruhr (passing Cologne as its harbour). They show a straight line with a similar distance to the coast. This structure allows a slightly different interpretation of P_{3000km}.

Polarities in a radius of 300km

In a radius of R = 300km, smaller rivers polarise their harbours along the coast. At this level of scale, the continental and fluvial polarities appear as highways. Traffic networks follow their own laws of hierarchy (see *Fig. 101* on page 165). The suggested hierarchy in *Fig. 168* may gradually change in a more direct connection between Paris and Berlin. The Randstad may become the harbour of the 'Metropolregion Rhein-Ruhr' at the Rhine-axis. It came into being through the Industrial Revolution, based on coal. Coal mining was concentrated along a line from the Belgian Borinage to the German Ruhrgebiet. Its historical infrastructure crosses the river Rhine near Köln (Cologne), as a historical 'Coal-axis'. It is a potential short-cut in the P_{3000km}. The next section proceeds in a more structural way, where the morphological study concerning the distribution of lines stopped (see section 0 on page 164).

5.5 Networks

Artificial networks

The hierarchy of polarities may be clarified by studying the accompanying artificial networks, as a special kind of structural diversification. Rivers flow one way, from high to low, into the open sea. Their one-sided feeding branches get the form of a tree (see *Fig. 160*). A network of roads, however, is not necessarily 'open' at one side and 'closed' at the other side. Its meshes are at least two-sided, 'bipolar', and connected. The individual user may experience one polarity in the direction of her or his destination, but the arrangement of roads, used by many users both ways, requires a lattice instead of a tree[a] (see *Fig. 170*).

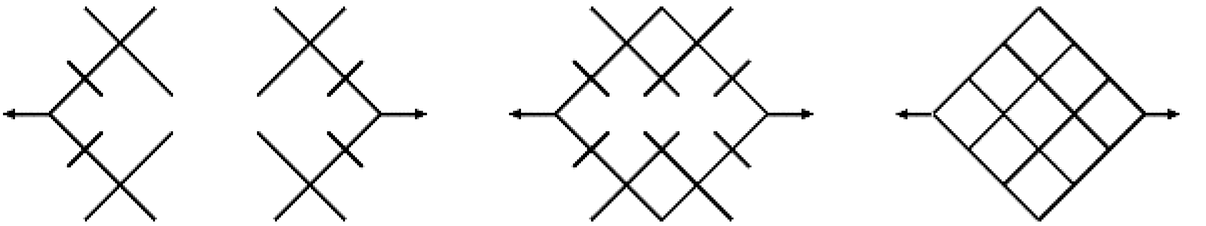

Fig. 170 A polar tree becomes a bipolar lattice

The form of the grid is not necessarily orthogonal, or even made up of square meshes, as it will be represented below for reasons of clarity. The grid may be irregular, but as soon as it contains a hierarchy with longer stretched lines of higher order, there is a tendency towards orthogonal arrangement (see *Fig. 99* on page 164). Irregular meshes, however, do have a perimeter/surface proportion. It makes them comparable with those of the squares. This proportion is 4 km/km^2 for a 1km x 1km square, but because the boundary is shared with adjacent squares, the 'network density' d equals 2 km/km^2. A 2 km x 0,66 km rectangle has the same network density. You cannot keep the same network density by narrowing a mesh that is proportional to its elongation (see *Fig. 102* on page 166). Elongation reduces the number of crossings until there are only parallel roads at a distance 1/d without side roads connecting them. Such a pattern of unconnected parallel lines is no longer called a network.

A road hierarchy

Connecting locations at larger distances requires larger roads where you can drive faster, and be undisturbed by crossings. The optimal reduction of investments, detours and loss of time may be reached if every third residential street is a wider neighbourhood road, if every third neighbourhood road is a wider district road and so on ('factor 3'[b]).
It may produce a hierarchy of roads, as summarised in *Fig. 171* , and drawn in *Fig. 172*.[c]
Fig. 171 refers to the radius of the served estates (10 inhabitants), ensembles (100 inhabitants), neighbourhoods (1000 inhabitants) and so on, as they are conceived of in the previous section. The length of the radius also serves as the length and width of (square) meshes (the distance between exits), which results in the typical network density of each road category (basis of comparison with irregular grids). The increasing design velocity requires wider lanes. A larger road requires more lanes, parallel roads, cycle paths and noise barriers, resulting in a larger width between the façades. Until the metropolitan highway, the slowly increasing capacity is not proportional to the increasing intensity that you may expect from an exponentially increasing served population, even if they use every larger road less per day, or per hour. If you leave a road category out, then the next will take over, increasing its exits, and probably causing traffic jams.

[a] Alexander(1977) *A pattern language* (New York) Oxford University Press
[b] Nes;Zijpp(2000) Scale-factor 3 for hierarchical road networks a natural phenomenon? (Delft) Trail Research school
[c] See http://team.bk.tudelft.nl/Publications/XLS/03bTrafficnetworks.xls to simulate alternatives and to draw profiles.

	m width between façades	m mesh size	km/km2 network density	Served inhabitants	km/hr design velocity	m lane width	# vehicles/hour capacity	# vehicles/hour intensity	# lanes
residential path	10	0,03	70	10	10	1,75	500	2	1
residential street	20	0,1	20	100	30	2,25	2 000	20	2
neighbourhood road	30	0,3	7	1 000	50	2,75	3 000	202	2
district road	40	1	2	10 000	70	3,25	4 000	1 042	2
urban highway	60	3	1	100 000	90	3,25	8 000	2 220	4
conurbation highway	70	10	0,2	1 000 000	110	3,25	16 000	10 400	8
regional highway	80	30	0,07		130	3,25	20 000	16 200	10
metropolitan highway	100	30	0,07	10 000 000	150	3,25	32 000	24 000	16
national highway		100	0,02		150	3,25			8
fluvial highway		300	0,007		150	3,25			4
continental highway		1000	0,002		150	3,25			4

Fig. 171 A hierarchy of roads

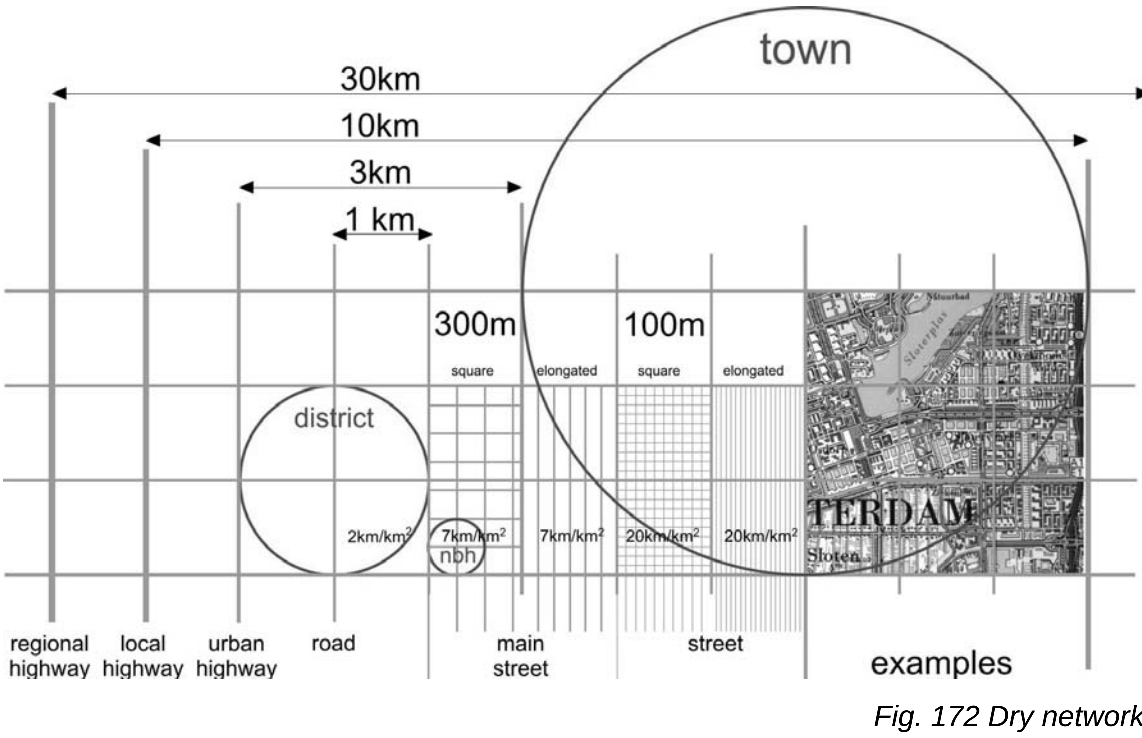

Fig. 172 Dry networks

The theoretical 'factor 3' results in 11 road categories. You may recognise the first 7 categories on a city map (see *Fig. 173*).

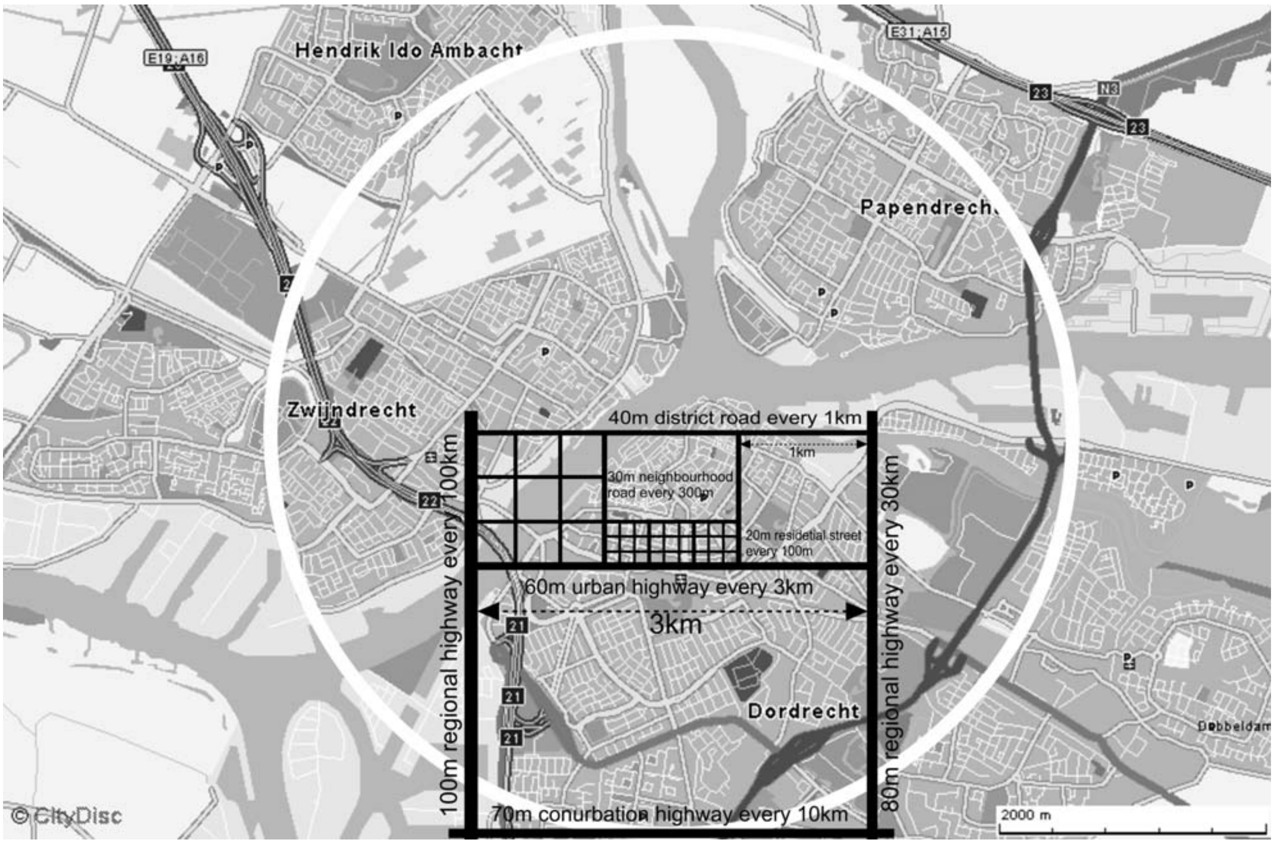

Fig. 173 R = 3km Dordrecht Seven road categories in a city map[a]

National and regional highways

According to *Fig. 171*, the theoretical mesh widths of continental, fluvial, national, regional and conurbation highways are 1000, 300, 100, 30 and 10km respectively. If the continental connection of *Fig. 168* operates as a primary national highway by superposition, then you should expect the next national highways at an approximately 100km distance of the first. In the highways of the Netherlands, you indeed may indicate two 100 x 100km slightly deformed meshes, which are linked up with the Eastward and Southward continental connections (see *Fig. 174*). It would result in two North-South and three West-East national highways. The fluvial South-Eastern connection distributes its traffic flow in Utrecht over the continental connection into Rotterdam, The Hague, Leiden, Amsterdam and the regional highways. In *Fig. 174*, the regional highways are simulated in elongated meshes, with approximately the same network density as a 30 x 30km mesh.

Settlements or connections as driving force

Fig. 175 shows the real distribution of highways, the urban population and the remaining relatively open spaces of the Netherlands as its counter-form. The location of settlements and open spaces may have determined or deformed the theoretical network, but connections and crossings also determined their location. The driving force may be different at different levels of scale.[b] *National* infrastructure works did not improve the economy of peripheral regions (Delfzijl), but *international* connections may improve the economy of cities (Lille by the Channel tunnel). If the classifications of 3m, 30m, 300, polarities as ‘sensoric’,

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[a] CityDisc(2000) Den Haag

[b] Jong(1998) Wat eerst: wonen, water, wegen of welvaart? Wat aanvankelijk een verband lijkt, blijkt soms toeval. **IN** Angremond;Huisman;Jong;Schiereck;Thissen;Broos;Herbergs**,** Watertovenaars. Delftse ideeen voor nog 200 jaar Rijkswaterstaat (Rotterdam) bèta Imagination Publishers p42-52 http://team.bk.tudelft.nl/Publications/1998/Wat eerst.htm

and those of 10m, 100m and 1000m as 'motoric' are right, then a 1000km connection may be a driving force, but a 300km connection might not. Urban design may start through the connections, or by the built environment, but the best way may be scale dependent.

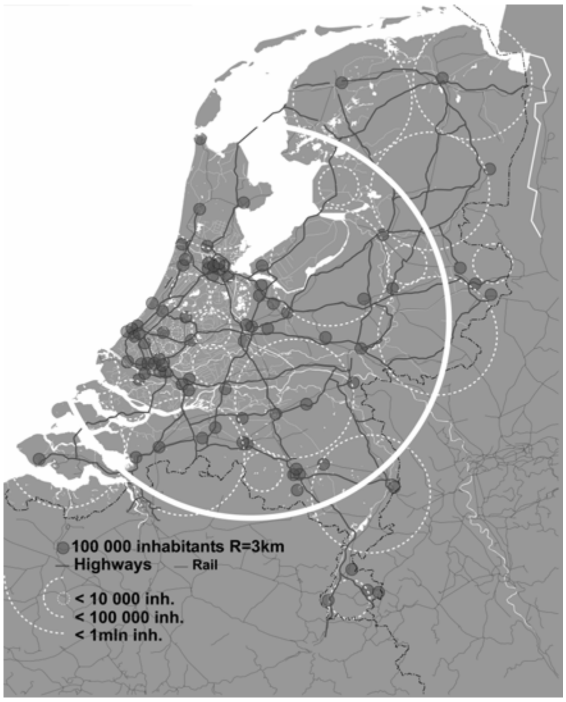

Fig. 174 National and regional highways

Fig. 175 Distribution of urban population R=100km

Artificial wet networks

Artificial wet networks in lowlands have several functions, including drainage, and serving as a water supply in the summer. The water may flow both ways, making them bipolar. Their hierarchy is surprisingly similar to the hierarchy of the road network above (see *Fig. 176*).

NETWORK		WET		DRY	
km/km^2 density	km mesh size	m width 1%	NAME	m width	NAME
70	0,03	0.3	**trench**	10	**residential path**
20	0,1	1	**small ditch**	20	**residential street**
7	0,3	3	**ditch**	30	**neighbourhood road**
2	1	10	**watercourse**	40	**district road**
0,7	3	30	**race**	60	**urban highway**
0,2	10	100	**brook/canal**	70	**conurbation highway**
0,07	30	300	**river/waterway**	80	**regional highway**
0,02	100	1000	**stream/pond**		**national highway**
	300	3000	**lake**		**fluvial highway**
	1000	$\geq$10000	**sea**		**continental highway**

Fig. 176 Similarities between wet and dry networks

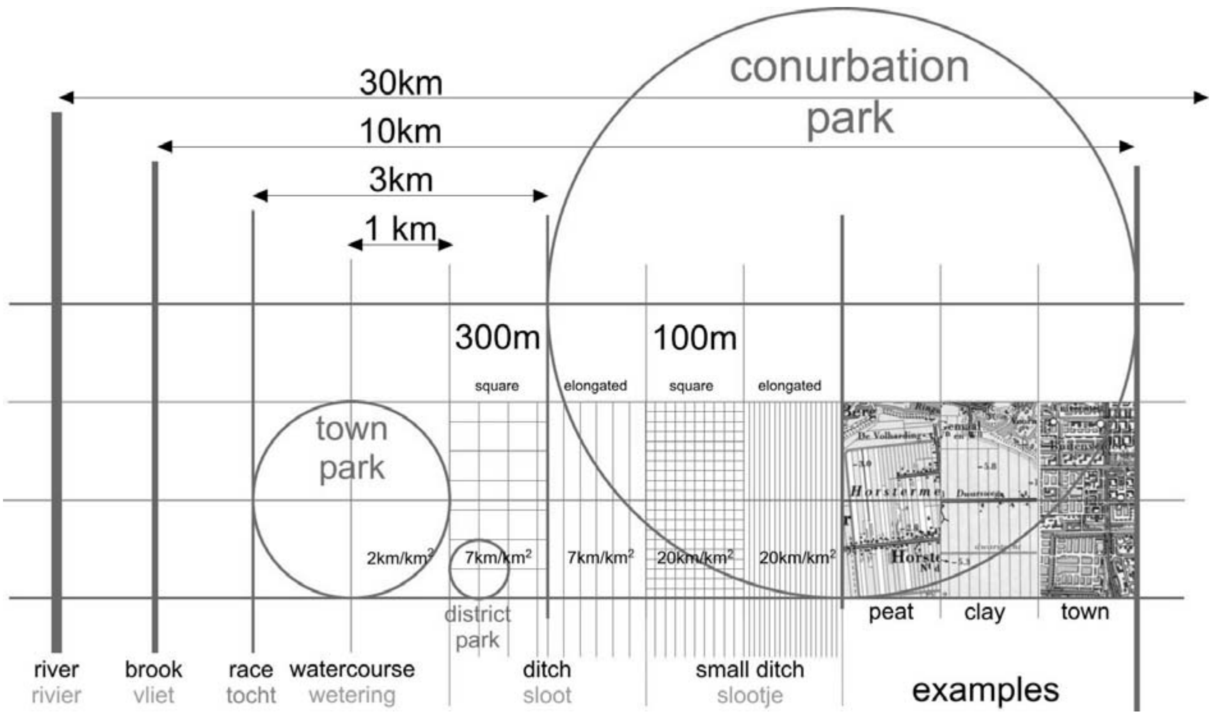

Fig. 177 Wet networks

Fig. 177 shows the wet equivalents of *Fig. 172* , with examples of small, elongated ditches on peat soils, larger elongated ditches on clay grounds, and small square watercourses on sandy urban soils. The drainage distance of small ditches, however, is dependent on factors other than the permeability of soil (peat, clay, sand), such as the precipitation, the desired groundwater level and the desired difference of water level in between the drains.[a]

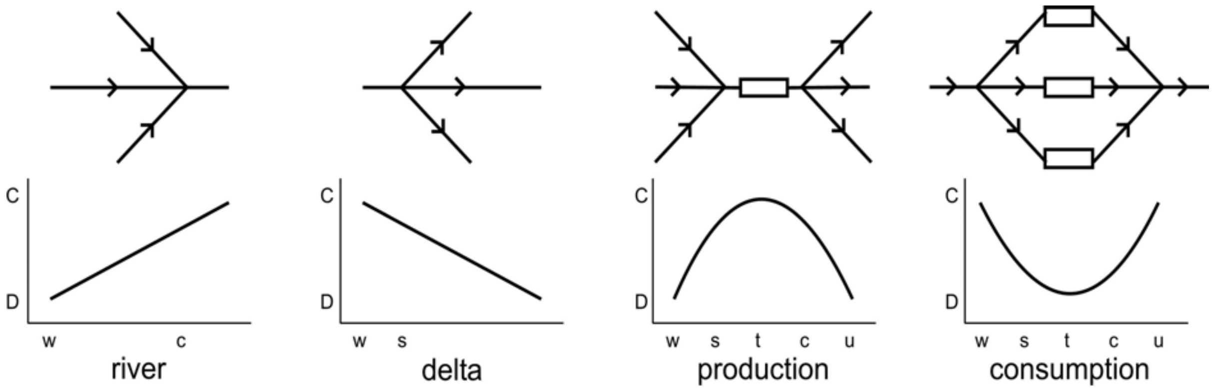

Fig. 178 Collecting, distributing, processing logistics

[a] See http://team.bk.tudelft.nl/Publications/XLS/03aWater.xls

One-way artificial networks

Many other artificial networks, however, are polarised. Cables, pipes, and the logistics of production and consumption in general, are one-way systems, with an input and an output. Their structure contains collecting and distributing phases, with processing operations in between (see *Fig. 178*).Collecting and distributing phases are well-known from rivers and deltas. Collecting phases concentrate (C), while distributing phases de-concentrate (D). Production is a process between winning (w) and use (u). The process contains phases of selection s (e.g. a blast furnace selecting iron from ore), transformation t (making components) and combination c (assembly). These phases determine the content, form and structure of products, which may be a sequence of decreasing energy and nuisance at different locations, with different kinds of transport in between. Consumption, mainly dispersed in households, is a set of similar processes between distribution (goods and services) and collection (labour, leisure and waste).

Urban flows

These flows of materials, energy or information, are mainly neglected in macro- and micro-economics, and in urban design. Intermediate deliveries do not play a role in the calculation of a gross national or regional product. They are difficult to register, and they change through every transaction. A meso-economic method to understand these flows is input-output analysis, a matrix of (mainly industrial) branches at both axes and their mutual deliveries in every cell. From a viewpoint of urban design, however, it may be useful to determine at which level of scale the processing and transport operations can be centralised or decentralised, and which infrastructure can be built to combine them (see *Fig. 179*). Centralisation starts at the baseline of individual survival with collection (raising lines in *Fig. 179*). Selection, transformation and combination have been centralised through the evolution of technology (specialised processing and transport). This requires a distributive system (descending lines) into the end users. Many more dots and lines can be drawn to follow and estimate the centralisation or decentralisation of economic branches, and their mutual deliveries and dependencies.

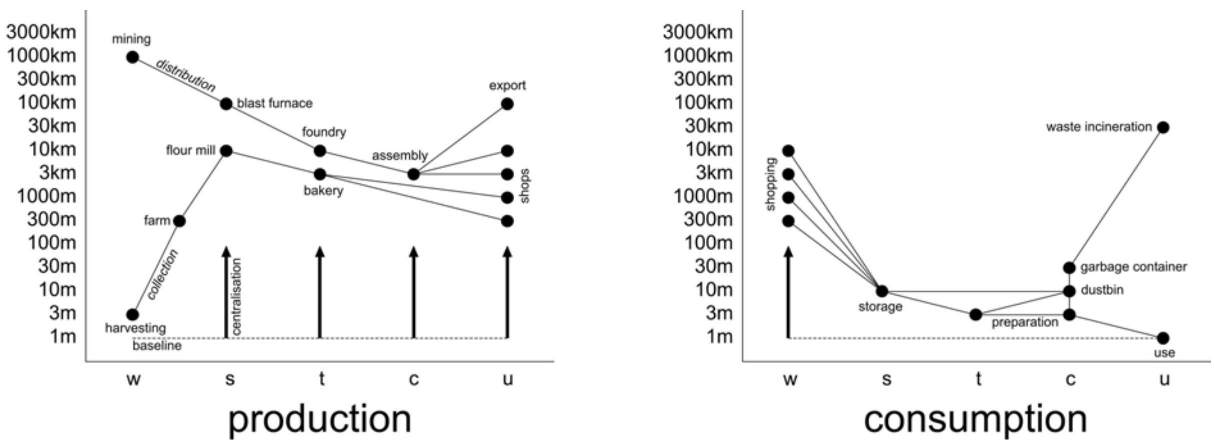

Fig. 179 Spatial logistics

5.6 Structural diversification

Existing structural diversity R=1km

Fig. 180 shows a R=1km area at the boundary of an urban area between a waterway and a highway. This already offers a P_{3km} and a P_{1km} for diversification. An orthopolar arrangement of P_{300m}. around the P_{1km} ,then, seems obvious.
This analysis into rigid arrows may unveil an existing diversity, but to use and develop that diversity through design, you should make the instrument of polarity more flexible. Forget the rigidity of the arrows, remember that its scale is *nominal*, covering a range of scales, even overlapping its neighbours (see *Fig. 17 Defining Nominal* on page 52).
Draw polarities by hand. Mistakes are a source of new ideas. The computer is filled with probabilities. Take a step outside this area of probability into the realm of less probable possibilities (see *Fig. 2 Possible, probable, and desirable futures* on page 17).

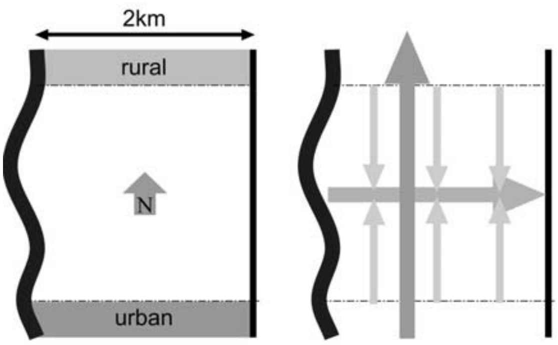

Fig. 180 R=1km Existing polarisations

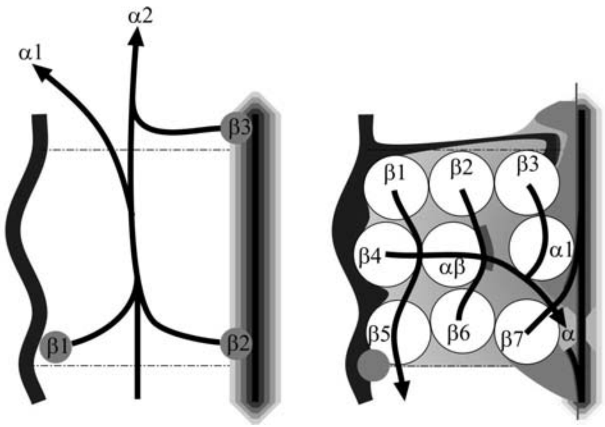

Fig. 181 Splitting, curving, combining

Diversifying a 3km polarity

Splitting and curving the P_{3km} , produces a sketch for primary appointments (see *Fig. 181*). Open views $\alpha 1$ (water) and $\alpha 2$ (rural) should be protected and gradually prepared within the urban area, according to the direction of P_{3km}, starting in $\beta 1_{3km}$, $\beta 2_{3km}$ and $\beta 3_{3km}$.
The Southern part should be different from the Northern part. This includes an intended difference between the Northern $\beta 3_{3km}$ and the Southern $\beta 1_{3km}$ or $\beta 2_{3km}$. The difference between the obviously quiet Western $\beta 1_{3km}$ and the dynamic Eastern $\beta 2_{3km}$ or $\beta 3_{3km}$ (e.g. a noisy swimming pool) is determined by P_{1km}.

Diversifying a 1km polarity

Splitting, curving and combining P_{1km} with the P_{300m} arragement, enables a second sketch by hand. This suggests a branched main road connecting the neighbourhoods to a given highway exit for further discussion. The 9 circles at R=300m provide ample space for 10 000 inhabitants and jobs. This low gross density is chosen for reasons of clarity. Drawing these circles carefully determines a proper dispersion of P_{1km} branches. It provisionally suggests possible extensions of the waterway, a park system, and the location for a district centre. It also develops the previous β_{3km} ideas further. The P_{1km} is not only motoric. Its sensoric character may suggest an increasing green density of plantation in the East. The Eastern neighbourhoods at the highway $\beta 3_{1km}$, $\beta 7_{1km}$ and $\alpha 1_{1km}$ (locating the jobs) may contain the most dynamic functions; the Western neighbourhoods on the waterfront $\beta 1_{1km}$, $\beta 4_{1km}$ and $\beta 5_{1km}$ provide quiet locations. The central $\alpha\beta$ neighbourhood with its adjacent district park provides space for district facilities. It produces a second P_{1km} arrangement, which is not to be discussed here.

Different residential identities in R=3km

The open α_{3km} (views at the still open land) and the closed β_{3km} (specific potentials at the corners of the area) have got a strong locational identity, but how to realise the values in between α and β of P_{3km} as a gradient? What is a useful content or form to diversify that part of the structure, and to make your orientation between South and North in the district self-evident? The variables of *Fig. 74* on page 114 provide many possibilities, but suppose you choose to vary the degree of seclusion of dwelling types (see *Fig. 182*). Detached houses are most open to the environment, and split-level drive-in dwellings in rows are more closed. Many more values may be defined legally, in order to diversify this variable in the regulations of the plan. But this form variable is related to density, economic value, status, age and lifestyle. Do you want to add these inherently related values? Do they fit in the area? You cannot avoid functional considerations here, but they fit in a coherent view on content, form and structure. A higher density in the Southern part than in the Northern part may make sense.

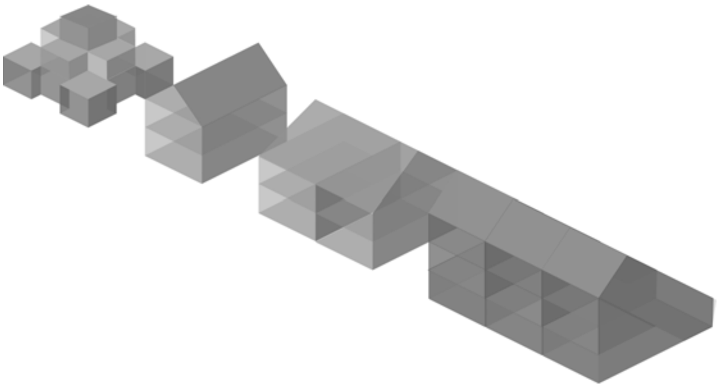

Fig. 182 Open-closed dwellings R=30m in P_{3km}

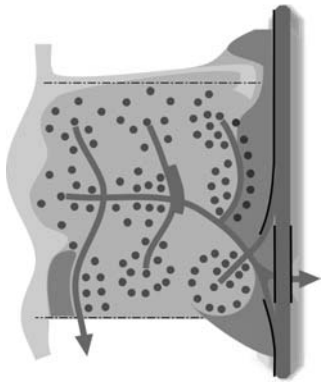

Fig. 183 Density R=1km

In *Fig. 183* , 100 R=30m dots, each representing floor space for 100 inhabitants (black) or jobs (grey), replace the neighbourhood circles of *Fig. 181*. High value and status in the North may protect the views of open land in the future (α_{3km}). Older people, just like family people with young children, do not want to live in very high or low densities. They need facilities in their neighbourhood ($\alpha\beta_{3km}$). Consumers look for high densities and facilities, but careerists may want to live in drive-in dwellings near the exits (β_{3km}, α_{1km}), or in representative environments (β_{3km}, β_{1km}). The question remains if the Southern neighbourhood in between both locations deserves a high density. The sketch of *Fig. 181* did not promise a high density. This shows how important even a very simple sketch as *Fig. 181* in the beginning may be, if it is passed and approved as a concept. In practice, you can refer afterwards to its implicit decisions.

Small components determining a large structure

In the previous paragraph, the 'seclusion' of dwellings R=30m, represented in *Fig. 182* is used to 'fill' a polarity that is operational at R=3km. Its relation with a gradually changing density, in a radius R=3km, may be relevant, but it shows also, how a sequence of small components may strengthen a much larger intended structure. This relation between different levels of scale, and their different characteristics, is something other than the relation between levels of scale, which is caused by the synpolar, orthopolar or counterpolar arrangements of *Fig. 145* on page 190. The polarities in *Fig. 182* do not play a role. Their overall characteristic of 'seclusion' does. To strengthen a large polarity, you should not only look for variables that are operational at the same scale *Fig. 74* on page 114.

The impact of curves

Deviations from a straight line will introduce many differences, at different levels of scale. This can be illustrated best at R=100m. In *Fig. 184* and *Fig. 186*, an area of 150 x 80m is filled with 52 two-story dwellings of approximately 5 x 9m, on average (ensemble-FSI = 40% with ample 70 parking lots). The dwellings, however, are clearly distinguished in 'extravert' and 'introvert' dwellings (see the divergent and convergent arrows of *Fig. 184*). These names do justice to any of their characteristics. The angle between the extravert lots is 10^{o}, and 20^{o} between the introvert lots to keep an approximately 5m dwelling width (see *Fig. 185*). Consequently, the introvert lots are twice the size of the extravert ones, in favour of their back garden and the width of their rear façade. They are substantially oriented towards the back side, leaving space for a kitchen in the rear. The extravert dwellings, however, will probably obtain a kitchen in the front.

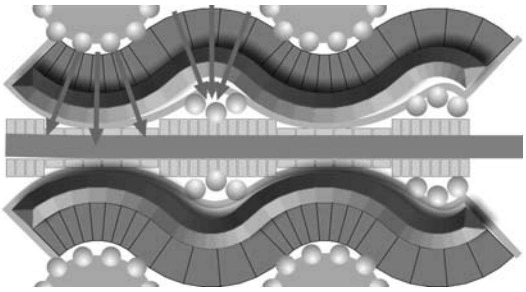

Fig. 184 R=30m Symmetric

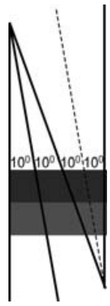

Fig. 185

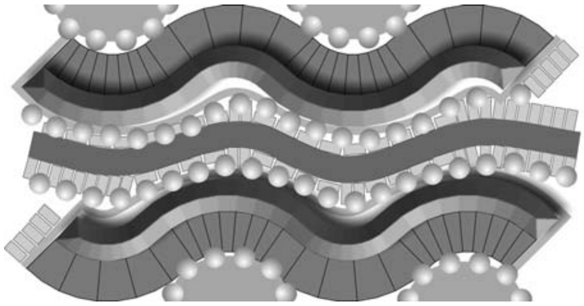

Fig. 186 R=30m Parallel

A curvature has substantial impacts on the public space, too. It diversifies the views on the façades, generating more surprises. The impacts, however, are different if the curvatures at both sides of a street are either symmetrical or parallel. In the symmetrical case (see *Fig. 184*), the street is articulated in wider and narrower parts, offering many possibilities to diversify its exits and inner furnishings. The introvert dwellings obtain a wider, but enclosed space at their front, but the extravert dwellings paradoxically do not obtain a view. They are directly confronted with their opposite neighbours (and their kitchens). In the parallel case (see *Fig. 186*) they obtain a view. In addition, the street may follow the curvature more easily, which reduces the traffic velocity spontaneously, but it becomes less diversified between the exits and inner parts of the street.

Extravert and introvert

The extravert and introvert character of buildings is a structural feature of divergent or convergent polarisation. It immediately obtains functional, social and cultural associations, which are illustrated through the difference between the external colonnades of a Greek temple, and the internal colonnades of an Egyptian temple or a Roman basilica.

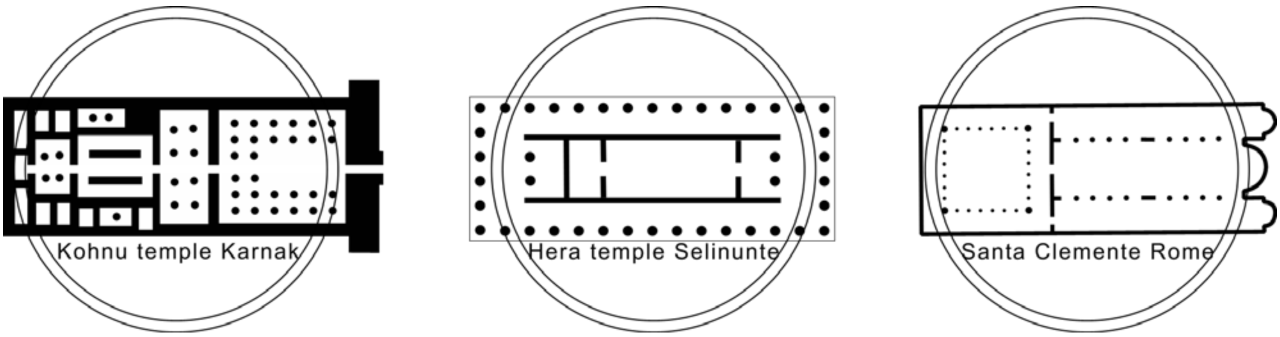

Fig. 187 Introvert Egyptian, extravert Greek, introvert Roman R=30m

Prototypical structures of landscape

Mountains, hills, and plateaus are divergent, while valleys are convergent. These are prototypical structures of extraverted and introverted landscapes. Decreasing altitude is followed by many variables, such as the accumulation of water, increasing temperature, vegetation and human use. At a larger scale, however, the lowlands, their harbours, cities and the sea are the open counterpart of inland highlands, with their valleys and villages. Its consequence is a difference of orientation on trade and agriculture. Invasions from the sea may have played an underestimated role in the origin of Western culture at the coasts of the Aegean Sea. Ionian invaders settled in the lower settlements, such as Milete, for outward trade, driving Aegean inhabitants inland. According to Herodotos[a], they killed the men, taking their daughters as their wives. If you take that seriously, this kind of connecting cultures may have happened more often, mixing an Appollonian and an older Dionysian culture. The remaining secret mystery cults may have seduced the busy, rational tradesmen into joining the seasonal grape harvest, or spring bacchanals in the mountains. The ecstatic Dionysian mysteries may have been a prototypical escape from urban life, as it lives on in our customary holidays and carnivals. It may have been the foundation for a continuous awareness of an alternative. One of its earliest representatives was Thales of Milete.

Structure and function

If a structure is *operational*, then it may *perform* a function in a larger structure. To know which function it performs, you must know the larger structure. If you ask me: “What is your function?”, and I answer: “Director!”, then your next question should be “Director *of what*?”. It could be a director of a one-person family, or a director of a large company.

If you want to remove a wall in your house, you must ask yourself whether it has a function in the bearing structure. The same counts for a road in a traffic system, a dike in the water system, a person in an organisation, a word in a sentence, and so on.

A function is necessarily part of a larger structure, but it also supposes a smaller operational structure that can perform that function. Thus, function is a connection between two levels of structure, and is consequently scale-bound. At any level of scale, however, you should distinguish the outward function *of* something, from the inward function *for* something. The next chapter restricts itself to location bound functions for a human population and its habitat, and the other way around. These locational functions may function directly population, or indirectly for their habitat. To put it the other way around, a population or a habitat has an ‘inward’ function for the performing structures

[a] Herodotus (440BC) *Histories 1 Books 1-2* (Cambridge Massachusetts1975) Harvard University Press Loeb Classical Library series