A Conceptual Model for Concurrent Engineering in Building Design according to Domain Theory

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ABSTRACT

Concurrent engineering is a design strategy in which various designers participate in a co-ordinated parallel process. In this process series of functions are simultaneously integrated into a common form. Processes of this type ask for the identification, definition and specification of relatively independent design fields. They also ask for specific design knowledge designers should master in order to participate in these processes. The paper presents a conceptual model of co-ordinated parallel design processes in which architectural space is simultaneously defined in the intersection of three systems: a morphological or level-bound system, a functional or domain-bound system and a procedural or phase-bound system.

Design strategies for concurrent engineering are concerned with process design, a design task which is comparable to the design of objects. For successfully accomplishing this task, knowledge is needed of the structural properties of objects and systems; more specifically of the morphological, functional and procedural levels which condition the design fields from which these objects emerge, of the series of generic forms which condition their appearance and of the typological knowledge which conditions their coherence in the overall process.

0 INTRODUCTION

Concurrent engineering is the name given to a specific design strategy characterized by simultaneous action by various categories of designers in a co-ordinated process. The process leads to the integration of factors by corresponding actors. Three ways to describe concurrent engineering correspond with three groups of synonyms found in literature:
- Parallel or simultaneous design refers to the form of the process, the way it can be visualized: strings of activities, linked both in series and parallel.
- Integral and/or integrated design refers to the function of the process: uniting a range of functions in a form as intermediate state and as ultimate outcome of the design process.
- Participatory design, refers to the process of decision-making by actors, agents or parties and their contribution of experience, knowledge and creativity

Concurrent engineering processes, is our assumption, have to be described simultaneously by their formal, functional and procedural properties. This is the way how, according to Domain Theory, the development of artifacts in general, both in terms of states and processes, is considered.

Concurrent engineering is considered to provide an adequate model for the description
of natural design processes in which factors are replaced by actors; the Aristotelian notion of processes "in instanti" is replaced by the notion of simultaneousness.

0.1 A Conceptual Model of Design

Domain Theory - an application of General Systems Theory, developed by the authors (Bax, 1979) and (Trum, 1979) - is a body of knowledge presenting a design frame which guides the description of artifacts as the result of a design process, and reciprocally the prescription of design processes resulting in artifacts which fit in a given context. The frame accommodates both, states and activities transforming these states, both for retrospective and prospective purposes, within a three-dimensional matrix with Form, Function and Process as axes.

More specifically, the frame accommodates the description and prescription of relatively autonomous design fields and spaces whose partial designs are, or have to be integrated in an overall, architectural design. The frame guides the diagnosis of the existing artifact and the prognosis of the future existence of an artifact, both as the result of a process and as the balance of qualities and intentions in the various design fields and their actors. For this reason the axes of the Form-Function-Process-matrix are specified respectively in Levels, Domains and Phases, defining corresponding design fields and spaces. This specified matrix is the so called GOM-model. This static modality of the model accommodates a dynamic modality in which three types of processes are discerned: Ordonnance, Integration and Differentiation processes.

More generally, the design frame allows for the description of each Concept in a Taxonomy of Concepts, covering the whole field of architectural design in a complete and consistent way. Concepts are structured conform the GOM-model. They combine images and ideas and define classes of design fields, each with its own culture and function bound typology. The Taxonomy has three hierarchical ordered levels: design, planning and policy, each level forming a triad of basic concepts. Three kinds of Concepts can be distinguished: basic concepts, scale concepts (integrating basic concepts) and architectural concepts (integrating scale concepts).

It is argued that the use of such a design frame as a conceptual model, is a necessary condition for the analysis of historical processes and for the design of design strategies, of which concurrent engineering is a specific case.

0.2 Conditions for concurrent engineering

The term concurrent engineering refers to a wide scope of processes involving the phases of policy-making, planning, actual design, construction, use, and demolition, and beside that the aspects of design, control and management of these processes. For all these phases and aspects the principles of concurrent engineering are applicable. The content of this paper is restricted to the concurrent design phase: the description of this phase in terms of design fields and spaces as a base for the design of future design processes.
The static and the dynamic modality of the GOM-model refer to objects and processes respectively. A project is defined by both modalities: an object with regard to its procedural aspects, or a process with regard to its substantial aspects.

Objects are considered as systems, designed in a design space or field. The term space is used when the field is defined in a qualitative and quantitative way, restricting the activities of the designer. A design space is demarcated from its environment and articulated for further detailing; interfaces with other spaces are specified.

During the design process, systems or objects considered as systems, are transformed from one state to another. Processes are composed of activities, realising these transformations.

Design spaces and design activities together define design tasks, carried out by design agents, or designers. A design agent can be a person, but also a team, an office, or an organization which agrees about decisions concerning the transformation.

The two modalities of the GOM-model together, define an object in a process of transformation. States of objects in relation with activities are represented as fields in a 2-dimensional matrix, defined by the articulation of a process-, or x-axis, and an object-, or y-axis. Both axis refer to Process, Form and Function, but interpreted respectively in a dynamic and a static way.

Referring to these dimensions, the articulations of the object-axis are: Phases, Levels and Domains, defining respectively (Bax, 1989):
- Phase-bound objects and spaces, with reference to the Process-dimension;
- Level-bound objects and spaces, with reference to the Form-dimension;
- Domain-bound objects and spaces, with reference to the Function-dimension.

The articulations of the process-axis are: Differentiation, Ordonnance and Integration, defining respectively (Bax, 1989):
- Differentiation-bound activities, with reference to the Process-dimension;
- Ordonnance-bound activities, with reference to the Form-dimension;
- Integration-bound process, with reference to the Function-dimension.

The fields defined by the articulations of the object- and process-axis define tasks of designers, composed of spaces and activities, in a project.

The conceptual frame of the matrix defines design tasks and types or categories of designers. The tasks can be observed in a historic or natural process, or can be components of a future process, the design of a process, or a design strategy, characterized by a specific arrangement of tasks, ordered in time. Their ordering is a combination of serial and parallel links.

In order to arrange these tasks in a controlled, co-ordinated process, two main conditions have to be fulfilled:

1. Design tasks have to be defined within the same procedural, formal and functional frame, and
2. Levels of specification of objects have to be matched with regard to the
Figure 1: Conceptual model of co-ordinated design tasks

procedural, formal and functional articulations of the frame, in which - in architectural design - the formal articulation is the dominant one.

The definition of levels of specification of objects has to be based on the notion of structural or generic properties of the various states of an object in a process, which means that - if confronted with a context - the object must allow for variant solutions. It is claimed that the GOM-model fulfils these conditions, or can be helpful in this respect.

Condition 1 is the subject of par.1, Design Tasks. In a hierarchy three categories of design tasks or categories are distinguished, based on their span of control in the
project. In par. 3, Design Strategy, a conceptual model of a concurrent design process is given, based on the results of the previous paragraphs.

1 DESIGN TASKS

Design tasks in the object-process-matrix, or project-matrix, are defined on a certain level of specification (Fig.1). Each field of the matrix defines a space/activity-task, which can be specified in sub-divisions of space and activity. For example: Level-bound space can be specified in levels of environment of the object, the object itself and differentiation of the object under concern, and each activity can be specified in sub-processes of analysis, synthesis and evaluation, forming a sub-matrix which is operational in each field of the matrix under consideration.

Each field of the matrix defines a (generic) task, for example:
- The central field of the matrix, level-bound space/ordonnance-bound activity, defines a task in which a designer, aware of the overall field of the matrix, elaborates the transformation of an object or system, e.g. a building, with respect to the formal requirements of objects on other levels, e.g. environment and detailing.
- Level-bound space/integration bound activity defines a task (...) with respect to the functional requirements of objects in other domains, e.g. usability, makability, stability.
- Level-bound space/differentiation-bound activity defines a task (...) with respect to the object in other phases, e.g. previous and next to come.

Within the matrix three main design tasks can be discerned on the diagonal of the matrix, stressing a:
- Process-oriented task (Phase-bound space/ Differentiation-bound activity),
- Form-oriented task (Level-bound space/Ordonnance-bound activity), and a
- Function-oriented task (Domain-bound space/Integration-bound activity).

Within the matrix three areas of tasks can be discerned, also situated on the diagonal of the matrix, which are spans of control, with respect to co-ordination of tasks.
- The first area, (3x3 fields), is the complete matrix, Phase-Level-Domain/Differentiation-Ordonnance-Integration, co-ordinated in the Process-oriented task, or Process-design; First category designer;
- The second area, (2x2 fields)-part of the matrix, Level-Domain/Ordonnance-Integration, co-ordinated by the Form-oriented task, or Form-design; Second category designer;
- The third area, (1x1 field)-part of the matrix, Domain/Integration, co-ordinated by the Function-oriented task, or Function-design; Third category designer.

The intensity of the first area of tasks is, because of its global nature, less than that of the second and third area. The number given to the area of tasks, implies no hierarchy in the military or administrative sense; in fact, all tasks can be fulfilled by one person.
The spans of control correspond on a conceptual level to three categories of designers, a first, a second and a third category, which function as model-designers, coded 1, 2 and 3, in a design process, presented in par 3.

Using the Taxonomy as a reference, the first category corresponds to the policy and planning level, and the second and third category to the design level. More specifically, the Professional Concept is the concept in which physical systems and elements are considered in their relation with design tasks.

In relation with praxis of architectural design: each architect is filling in (parts of) the three categories. He designs his strategy, he makes form propositions and puts them to a functional test. Sometimes he covers a specific domain, mostly that of usability.

2 DESIGN SPACE

From the introduction it will be clear that different design tasks have to share common features in order to create the necessary conditions for co-ordination. In this respect they have to share a common procedural, morphological and functional design frame.

In architectural design, traditionally, the demarcation and articulation of space and activities is based on the notion of scale or levels. Scale in this respect is not only the relation between the dimensions of an object with the dimensions of its representation in a model, e.g. a drawing, but it also means the ordering of a process of imaging from the presentation of the design for the commissioner at beginning of the process up till the instruction for the production of the building on the site for the contractor. In the architectural profession the term "scale" is also the indication of spatial quality, which brings the dimensions of the building in relation with the user or the beholder of the building: "a building has a human scale". Scale, or the division of space in a conceptual ordering of levels of measurement is as old as the theory of architecture: in his Ten Books on Architecture, Vitruvius expressed this notion in his definition of the notions of "ordinatio" (besides "dispositio" and "distributio"). Measure, position and elegance were combined in a design frame which still is valid today. However, the notion lacks an explicit procedural dimension. This addition is the subject of Bax's thesis "Metem met twee maten" (Bax, 1975).

The terms of scale and levels are handled as synonyms as far as the notion of level refers to form and space. In architectural design form and its articulation in levels is the dominant dimension of the design frame. It orders the dimensions of process and function as well.

This is a consequence of these dimensions being the dimensions of one and the same physical and spatial entity, sharing the same design frame. Level-bound spaces are crossing function- and phase-spaces and articulate them in levels: functional levels imposing a hierarchy in functional requirements and a hierarchy in a procedural organization.

This property of spatial entities in a common design frame can be explained also in
an other way. Each spatial entity always is considered to exist simultaneously in its dimensions of form, function and space. This regards to each phase of the process, from the beginning to the very end of the process. So, it is argued that for that reason not only generic forms, but also generic functions have to be distinguished. Their content is supposed to be corresponding with the various phases in the process, from initial general to final specific in its definition. In a design task decisions are taken by parties about elements based on their formal and functional properties within a context defined in the same dimensions. So, there are degrees of specification in a hierarchy, not only in form, but also in function and in the parties who are responsible for the decisions in the process. This means that there has to be a matching of the levels of form, function and process. This is considered to be a condition for the definition of design spaces and tasks. This regards in general to each type of design, subject to policy and planning, and more specifically to concurrent design.

2.1 Levels in formal spaces

Level-, domain- and phase-bound systems are three systems defining simultaneously a physical-spatial entity. These dimensions are conditioning and co-ordinating design and the execution of the design process. This study supposes principal equivalence of these dimensions. However, in architectural design, the design of a process is not well imaginable when the demarcations and articulations of the functional and formal design are not defined. In this sense, according to design practice, an order of sequence: form, function and process seems important, adding to the well known adagium of Sullivan a third item: process. This means that all dimensions are present all the time, but that in different phases accents will be put on different dimensions.

The specific position of form is also explainable because traditionally in the design process, form has the property to function as a common base for the functions parties want to give to them. It is an integration framework “par excellence” that by its possibilities and restrictions can initiate, condition and co-ordinate a design process. It addresses imagination in a subjective way and allows for testing in an objective way. In this sense design primarily is form-making, and the thesis seems defensible that actual participation of parties in design processes is only possible when the participating parties have the skill to use form as a common vehicle. This is what designers, at least in architectural design processes, have in common; that is their common language, a language of form, exceeding (sub)cultural differences, and their differences can be found in the categories of goals they want to reach. Integration takes place within a certain level-space and within a certain phase-space in a design process. Just like domain-bound systems and phase-bound systems can be articulated in levels of specification, it is obvious that level-bound systems can be articulated in levels. This means that a differentiation can be made between general and specific forms. General forms are indicated as generic forms. The term "generic" has two meanings, both of which are important. In the first pace the term has the
denotation: form induced from specific instances, and in the second place the term "generic" has the connotation: form which has the capacity to generate new forms (of a more specific character). So, the term has its meaning in a field, determined by the processes of induction and deduction. The term will be used in this study in both its meanings. Generic forms are forms containing a physical and a regulative part; based on these rules an original, global form can be differentiated in a more detailed form. A form of this type has so-called structural properties.

A situation with structural properties is an "empty" or "open" situation and is as such of importance for the design of decision-making processes: it fixes the essential aspects of a situation and offers opportunities for the infill of that situation. The definition of the structural situation can be the task of another party than the further specification or differentiation of that situation. The notion of structure is of vital importance for the distinction of levels within a spatial system. A simple example is given here for explanation (Fig.2).

On each level a design process is characterised by the following equation: 

empty situation + programme of demands >> variant situations.

As can be observed in the scheme, the programme makes use of (physical) elements which are identical with empty situations from a higher level. This means that the same spatial entity functions simultaneously on two levels: on the higher level as a
situation and on the lower level as an element (of a programme). The mechanism for the distinction of levels in decision-making processes is based on the double role entities can play. It will be argued that the mechanism of the double role is not restricted to formal aspects, but is valid also for functional and procedural aspects of reality as well.

A level is defined by a set of elements as building stones which meets demands of a complete and consistent description, both for categories of situations and programmes, typical for the level under observation. However primarily formal elements, functional and procedural attributes can be attached to them.

Names of elements indicate their functional aspects. The number of elements of each level in a system of levels is comparable. This means that the degree of complexity on each levels is comparable as well.

Each level is determined by a standard measure or module with which elements and situations on that level can be measured. According the mechanism of the double role spatial, entities are measured with a "double standard" (Bax, 1975).

As a consequence, each level is characterised with a grid in which the fields (as elements of a very general situation) are measured in a fixed number of modules. A system of levels shows a hierarchy of modules, in which higher levels the modules are a multiple of the lower level modules, defining a "generic grid" (Bax and Knikkink, 1984).

Also as a consequence, each level is characterized wit a scale, like 1:1, 1:10, or 1:100. The generic grid is a representation of a hierarchy of levels, a scale of scales, providing for harmony or "ordinatio" in the overall design field, but also - as will be shown - for an ordering of functions and parties as well. This makes the generic grid an instrument for design and the design of processes.

The term "generic grid" refers literally to a grid, but the term can be used in a figurative sense as well, referring to demarcation and articulation of the overall design field in a system of levels, and to the methods and strategies based on that concept.

The design process starts, according to theory - and also in line with what architectural designers are doing implicitly - with the analysis of a situation in terms of pattern or according to our theory: structural situations and in the distinction of a system of levels, characteristic for that situation. A comparable process takes place in the synthesis of the elements of a programme of demands, the ordering in levels and the distinction of levels and structures which are characteristic for these levels.

In this way situation and programme, as starting points in a dialectic process, are gradually reconciled by the use of mediating structures, which by their very nature are defined both in formal and functional terms. This method, the method of the generic grid, discerns two main stages: the so called model-stage, resulting in a well defined system of levels that functions as a frame for the actual design tasks in the plan-stage. This method, which by the wide scope of its application has the nature of a design strategy, is tested in practice for a wide range of complex design activities, mostly on an urban scale (Bax and Knikkink, 1984).
The distinction of spatial levels is a necessary condition for the design of design strategies and, as a consequence, for concurrent design and engineering. The content of levels corresponds with the content of phases in a process. The design of the process takes place in the initial stages of the overall design process, before the conventional phase of preliminary and definitive design. More important however is that concurrent design reflects an attitude in design, which reflects the awareness of the designer of design tasks and the participation of co-designers; this attitude can be made manifest in all the stages of the design process.

Summarizing, we argue that in the context of concurrent design designers have to be form-makers, having knowledge and skills of generic forms which are relevant for the various levels of design. Besides this knowledge they have to have typological knowledge, not only of their own design field or space, but also of the overall, architectural design field to which they contribute. This typological type of knowledge is of a less abstract nature, referring to generic representations based on the conventions of their field, but is - literally - concrete in the sense that it is based on culture-bound experience and history of that field, in the sense of both form, function and process. This typological knowledge is a necessary condition for concurrent design, because it guarantees communication and coherence in the overall design process and their parties. The aspect of typological knowledge, however important for the subject of this study, will not be considered further in this paper.

2.2 Levels in functional spaces

Functions in Domain Theory are considered as functions in the mathematical sense of the word. This is a difference with architectural design practice where the notion of function is restricted to the domain of use and refers to "activities" as mentioned in a programma of demands, like sleeping, cooking, etc. In this study function means rules or prescriptions which state a relation between the properties of a system and the objectives which can be reached, both in terms of quality and quantity. Properties are elements of a set, called a "domain", and objectives are elements of a set, called "range". So, functions describe relations between domains and ranges. Properties and objectives are related in the same way as means and ends, or causes and effects. Functionality in design is primarily effectiveness (in a measurable way). This approach uses performance concepts, in Dutch building regulations in the form of the so-called Bouwbesluit.

In politology means and ends are structured in goal-fabrics or goal-trees: an hierarchical decomposition of a goal in the means, necessary to achieve that goal. On a lower level the means function as goals, etc. A functional entity, depending on the level of consideration, functions as a goal or as a means. Comparable with the distinction of spatial levels, the mechanism of the double role defines functional levels in a hierarchy of levels. In his book "Design Methods" John Christopher Jones (Jones, 1970) offers three related methods for the definition of functional levels:
"Stating Objectives", "Selecting Criteria" and "Specification Writing".

In Domain Theory categories of functions are discerned in a taxonomy of concepts *, which correspond with categories of functions in architectural design (Bax and Trum, 1993). All these concepts represent the articulation of design space, which are indicated as domain-spaces. These spaces correspond with design tasks. Domain spaces are articulated again in levels, which means that according to Jones, means and ends can be dealt with in a general or in a more specific way. Generic functions are functions which condition and co-ordinate more specific functions.

2.3 Levels in procedural spaces (organization and parties)

Phase space contains spatial (form) elements discerned by their functional attributes and by the parties who are responsible for decision-making of these elements. This means that it is possible to make a selection of complete (in three dimensions) defined elements, using parties as a criterion. Parties are at work in phases of design processes. It is possible to discern parties by the phases in which they are active; designing a process, reciprocally, it is suitable to discern phases defined by parties. When there is a hierarchy in the organization of a project, defining levels of agents or parties, then these categories of parties are defining an articulation of phase-space in actual phases.

Parties (as a consequence of representing a dimension in a three-dimensional model, just like physical and functional objects) can be discerned in three ways:
1) by the phase in which they are active,
2) by the level of the physical objects, and
3) by the domains of functional objects.

In architectural design practice, urban designers, architects, and component designers correspond with phases in a design process. Their respective design spaces correspond with levels of spatial elements or situations. All of them have to integrate the functions according to the taxonomy of concepts in architecture.
(The term architecture in this study does not refer to a specific spatial level, or to a specific category of artifacts, but refers to the coherence of all concepts in one form. One and the same object can be represented on various levels, independent of the phase in the design process. Names given to these levels are e.g.: urban environment, building, building component. So, a design can be represented on the level of urban environment, the level of building, or the level of building component, showing more detailed information on the lower level, but - according to a sort of law of Heisenberg - loosing at the same time information about location.)

Tasks of categories of designers, as mentioned above, can be expressed by reference to design spaces defined by levels, domains and phases. These traditional parties play roles, defined by tasks, in which the fixed roles, because of mainly social reasons, tend to fossilize design projects. Modern design projects, is our assumption, ask for a more open and flexible approach, in which the definition of tasks is prior to the roles. This is the main reason why this study emphasizes design tasks, giving the opportunity to (re)define roles in design.
2.4 Matching of levels in design spaces

According to the properties of the GOM-model, each dimension can be expressed in terms of the other two. This means that each form, function and party can be described in three ways. As mentioned above, parties can be discerned in three ways, and in the same way form and function can be discerned by the attributes: levels, domains and parties (or by their corresponding phase in a process). Taking levels, domains or phases as a criterion for selection, it is possible to define sets of elements: all elements of a given level, all elements of a given domain, all elements of a given phase.

It was also mentioned that in architectural design form - and as a consequence of that - the articulation in levels is the dominating principle. Not only for ordering form, but also for ordering function and process. That was the reason why the notion of level in relation with form, function and process was elaborated in the previous paragraphs. Design spaces are represented by the dimensions of the GOM-model. For reasons of explanation it is suitable to make another representation: three parallel columns, representing: form, function and process (party). In each column there is an articulation in levels. A horizontal line in this scheme represents an observable spatial element which in the view of the analyst has some coherence. Analyzing a historic (natural) process, it is possible to represent the substance of that project by the division of levels in the three columns. In a given design situation, each spatial element can be discerned by specifying its level in the corresponding column. The result of that analysis will be that there is no real correspondence of levels in the three columns.

This means that a given spatial element participates on different levels, depending of the column: the formal, functional and procedural levels will not coincide. This result is understandable because there is no common historic, natural criterium for the articulation of levels in form, function and process in hierarchies. Even the number of levels in three columns can differ. So, there is no convention in articulating these levels.

It is argued in this study that for the design of artificial, cultural processes it is suitable, or even necessary, to create a correspondence of levels with regard to form, function and process. Using a metaphor from physical science, a new "law of commun-icating vessels", in which all occurring entities are expressed in terms of form, seems a suitable mechanism for the ordering of space in order to make it discrete and as a consequence of that operational for design processes. The design of such a design space is the first activity in a design process. It is the task of the first category designer, a process-oriented designer to accomplish this task. This design space is an ordering of relative autonomous sub-design spaces, a condition for the co-ordination of simultaneous design activities (Fig.3). Simultaneity is not a property only characteristic for concurrent design, but also for design processes in general.
3 DESIGN STRATEGY

The oldest form for the representation of simultaneous processes is found in the world of music, the score. In other languages, like Dutch language, the word "partituur" exist, which gives a better indication of its meaning: to co-ordinate the participation of the various parties, the musicians, in a concert. A score is both, diachronically and synchronically organized, which corresponds with the way concurrent design
processes are organized. These processes are represented in the form of horizontally and vertically arranged states of objects, subject to activities, necessary to transform one state in another. The representation of a concurrent design process shown in Fig. 4 is a simplified version of such a process, presented in a report for the Dutch IOP-committee (Bax, 1985). The numbers of the design tasks in the scheme refer to categories of designers, as distinguished in the next paragraphs.

3.1 First category of designers

The presentation in the scheme is given on a certain level of representation, which means that a choice is made about the information we want to present; the well known cycle of design steps: analysis, synthesis, evaluation and their feedback loops, is not shown in the scheme, being of too low a level for our purposes. Also higher level information is not shown in the diagram. The design of design space, as mentioned in the previous paragraph, is not shown. This means that part of the task of the first category designer, which is primarily a process-oriented designer, is already executed and that there already exists an adequate demarcation of design space and an adequate articulation of that space in levels, domains and phases. In that design the principle of matching (communicating) levels is applied. This also means that there is an adequate strategy, which determines the parallel and serial ordering of activities in time, indicating terms, budgets and mandates of parties for these activities.

In this specific case a choice was made to create three parallel processes:
- a process leading to a physical plan,
- a process leading to a social plan (for the organization which will be housed in the realized building), and
- an economic plan (for the flow of money, investments and exploitation, in course of time).

These three plans take into account the demands regarding change and flexibility, according to a scenario-like programme of demands.

Part of the strategy is that within each parallel activity the content of a phase corresponds with the content of a level and with an order. This means that in the phase under consideration spatial situations and elements are taken into account which belong to e.g. the level of the building, or a sub-level of that level; design activities are represented on a scale e.g. 1:100. The various spatial levels are elaborated in subsequent phases of the design process.

Part of the strategy is also that within each parallel activity three domains are elaborated in a parallel way:
- the domain of usability,
- the domain of makability, and
- the domain of stability.

The scheme shows how the various activities are ordered in time.
3.2 Second category of designers

The task of a second category designer, who is primarily a form-oriented and level-bound designer, is, given the outlines of his level-space, to demarcate his design space more exactly and to articulate this space into domain spaces in such a way that he can co-ordinate the parties which are responsible for the three domains. He also creates a generic form by abduction and, at the end of the process within the phase under consideration, he induces the domain-bound variants to a new and differentiated generic form. This process is an integration process. He takes into account the characteristics of the environment (on a higher level) to which his design has to be tuned, and he also creates space for lower level decision-making in a process called ordonnance.

As the resulting form is more detailed, being the outcome of a differentiation-process, it is adequate to represent the design on a lower scale level, e.g. 1:10. At the end of the three activities of the phase, three plans result in three different orders: a physical, an economic and a social plan. In order to find a plan which suits the common interests of the three orders, it is necessary to generate variant generic forms in each order. As level-bound designers are principally order-bound designers too, and the interests involved exceed the borders of one order, this task is given to the first category designer.

3.3 Third category of designers

The task of the third-category designer, which is primarily a function-oriented and domain-bound designer, is to generate variant design solutions within his given domain-space. This means that he demarcates his situation, analyses the programme of demands in terms of his domain and when necessary, sub-domains, and deduces variant designs within the context of situation and programme. In this respect there are three parallel strings of activities within each domain: situation, programme and variants. This is the same string as shown in the example of Fig 2, the dressing of a table, introducing the concept of levels. The processes of integration, ordonnance and differentiation are also valid processes for designers of this category.

Fig. 4 shows a conceptual model for a concurrent design process. The tasks in the process are given a number corresponding with the categories of designers. A specific design process implies a transformation of the model as a consequence of the confrontation with a given context (situation and programme). In this respect the model has a generic format, which means that variant processes can be deduced from the (generic) model. Transformation of the model means for example: an other sequence and/or clustering of tasks; an other number of tasks (which means an other span of control). Also a further specification of tasks is possible by adding attributes to the task, e.g. parties in the organization.

In the latter case, a new code can be added to the tasks, e.g. a’s, b’s, etc., indicating different parties. In an extreme situation there is only one party, making all the decisions; in an other extreme situation there is a wide range of parties, which is the
case in concurrent design. Other codes can be added in order to determine the degree of involvement or mandates in the task, e.g. decision, co-decision, agreement, consultation, consent, etc.

Also attributes related to project management like type of documents, (re)sources, terms, development budget, instrumentation and other conditions can be added to the tasks, in this way specifying the conceptual model into a real plan or design strategy. The model functions as a description for the analysis of historic processes and also as the prescription of new processes fitting in a context. However speculative, it may be assumed, that the rules for the design of objects are similar to those for the design of processes, both being systems in a wider sense of the word. In the last case a higher order of processes is involved than in the previous pages. In both cases generic models, collected in libraries, are useful to initiate design processes.

The form of the design process: abducting a generic form, deducing variants and inducing a common form, which by its nature is less specific than the variants themselves, has, represented on a line indicating progress from general to specific, the characteristic of a so-called Echternach procession. In that procession the pilgrims
make two steps ahead and then one step back. Arthur Koestler states that this is a characteristic form for evolution processes in general; "reculer pour mieux sauter" is the ruling principle of these processes. Exactly with this type of processes, supported by information and computer technology, a new generation of self-generating design processes is forthcoming. These processes also will have the characteristics of concurrent design, because these characteristics are inherent to design in general, also, or even more specific, when the design process is a one-persons game.

4 EPILOGUE

Processes of concurrent design can be observed in various sectors of technological design. Differences in culture and terminology obscure the common features of these fields. Domain Theory offers a design frame which on a meta-level functions as a general interpreter which translates notions, concepts, methods and strategies from one field to another (Trum and Bax, 1990). It provides psychologists and analysts with instruments which enable them to describe and interpret the documents and the actions they observe in real, natural processes, connecting the natural world to a cultural world. It also provides a tool for management of design processes. The Stan Ackermans Institute, as a part of the Eindhoven University of Technology, accommodates a Design Research Centre, a.o. for the study of design processes in all the faculties of the university. Design is considered to be the core of technology, reason why it is subject of investigation, exploring the interdisciplinary space between disciplines, traditionally corresponding with these faculties. An interesting activity in this respect is the postgraduate course "Architectural Design Management Systems" (ADMS), which is active in the field between Architectural Design and Technology Management, two fields belonging to the realm of two faculties of the university. The conceptual model, presented in this paper, will be used to structure design processes in relation to their managerial environment.

5 NOTES

*) Structure
The term structural is used here in the meaning given to that term in the philosophy of French structuralism. Reality as we perceive it with our senses is manifest because underlying latent reality, confronted with a context generates variants. These variants are what we can perceive and in these set of variants we discover common structures, representing the latent reality. Structuralism, just like post modern end deconstructive philosophy supposes a layered form of reality. This reality can be read as a text on various levels, each level revealing a message with its own logic, complete and consistent, explaining each in its own way the reality as we perceive it. Structures can be discovered in a process of induction (stressing the relations between forms more than the actual forms); reciprocally, structures generate specific variants in a process of deduction. Structures have a form, just like variants have a form. It is however another type of form, another type of representation allowing it to function as a seed out of which grows the actual form. It is a generic form with a certain capacity based on geometry
and rules. It is a schematic form, a general model that generates actual plans. Examples of these generic forms are proportional measure systems, grids, zoning-systems, etc. in so far they represent certain qualities.)

Also a structural form can be represented in system-terms. Actually, a structure expresses the theory of a system. According to Boudon a structure is:
- a system of forms,
- a system of intentions, norms or standards, supporting functions or qualities, and
- a system of rules, which regulate processes of deduction and induction between general and specific forms.
(This definition reflects in a nutshell the linguistic distinctions between pragmatic, syntactic and semantic aspects of phenomena.)

7) Taxonomy of Concepts

Domain theory provides a taxonomy of concepts. (Fig. 5). Concepts are considered to be artifacts
and are structured according to the dimensions of the GOM-model: form, function as process.
The concepts correspond primarily with categories of functions, goals which have to be fulfilled by the artifact. These functions or performances can be defined on various levels of specification. Concepts
define design spaces and design tasks. So, also these tasks are of a general or specific nature, depending on its place in a design process.

In Domain Theory (on the lowest level of the taxonomy of concepts) three categories of functions are discerned, based on three modalities of change: (1) neutral towards change, stating a desired state, (2) positive towards change, stating the making of a new state, and (3) negative towards change, stating the keeping of an existing state. These categories are called "domains". These domains are respectively named:
- the domain of usability,
- the domain of makability, and
- the domain of stability.

The content of the domains corresponds with the goals of disciplines in design, related with (archetypical) parties like the user, the contractor and the (structural) engineer. Because of the open, functional definition of the domains, they offer a frame for the definition of tasks. Tasks can be formulated, independent of the parties as they exist just now. Reciprocally, roles (of parties) can be formulated as a cumulation of tasks.

The content of the domains correspond with concepts and a typology of its own. Each domain defines a design field, restricted to functional categories. Designs have the character of partial designs, which have to be integrated in an integral design. Designers are domain-bound designers.

The three domains define a level in a taxonomy of concepts. Each level of the taxonomy corresponds with a higher level concept: scale concepts, in which basic concepts are integrated. It is the task of the level-bound designers - nota bene: this notion of levels refers to spatial levels and not to levels in
the taxonomy - to condition and co-ordinate the tasks of domain-bound designers, resulting in a design (in the most restricted sense of the word).

In the taxonomy of concepts, scale concepts of a lower level define basic concepts of a higher level, using the mechanism of the double role to define (hierarchical) levels in the taxonomy. On that second level three categories of functions are discerned, based on the modalities of exchange between so called orders, contributing to an integral design on that level in the taxonomy of concepts. The following three orders, each with its own characteristic variables, and each composed of three domains, are distinguished:

- the physical order,
- the economic order, and
- the social order.

Characteristic for that level in the taxonomy is that exchange or substitution of categories of functions is possible and asked for to a relative high degree. This means that, depending on the nature of the design problem, there is a choice of means, stressing sometimes physical means, sometimes social means, etc. In architectural design the physical order is the dominating order. However, all orders represent design fields, generating partial designs, contributing to the integral design. Designers are order-bound designers, which are referred to as domain-bound designers (of a higher level) as well. The categories of functions correspond in practice of architectural design with categories of planners, reason why to this level of design is referred as that of the scale-concept of planning.

In the taxonomy of concepts, scale concepts of planning define basic concepts of a higher level, using the mechanism of the double role to define (hierarchical) levels in the taxonomy. On that third level three categories of functions are discerned, based on the modalities of reality, corresponding with three orientations of designers. Respectively reality is interpreted as (1) a system or work of design, (2) a system of stressing universal laws and knowledge structures, underpinning design, and as (3) a system of symbols, a world of meaning. The following categories are discerned, depending on their orientation and attitude or styles of designing:

- professional orientation, "pragmatic reality"
- scientific orientation, "hypo reality"
- artistic orientation, "hyper reality".

(When "modern" architects, with reference to Conceptual Art talk about "conceptual design", they are mostly elaborating only the Artistic Concept, which they, in a mis-interpretation of post modern philosophy, seem to consider as a "pars pro toto" of architectural design. It will be clear that this view is not shared by the authors.)

These concepts are basic concepts, contributing to the scale-concept of policy, the most general way to determine the philosophy, the theory, or the "poetica" of architectural design.

The scale concepts of design, planning and policy determine the three levels of the taxonomy, which have to be integrated in order to achieve an architectural concept. So, integration takes place on three levels: integration within the basic concept, integration in the scale concept, and integration within the architectural concept. These levels of integration are defined in a logic order, which doesn't mean that these order is corresponding with an order of time or sequence. Depending on the design strategy of a design project all these concepts are elaborated and co-ordinated in an overall architectural design in a specific sequence, which depends on the context of the project. There is only one condition, that really all these concepts play a role. In the project concepts can be integrated to various combinations of concepts which deviate from the concepts in the taxonomy; they are indicated as hybrid concepts.

As mentioned before, these concepts define design spaces and design tasks given to various parties in the process. They lead to partial designs represented in documents, characteristic and within the conventions of that discipline or party.
6 REFERENCES


