3. A Building Design Process Model

According to Domain Theory

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3.1 Introduction

In prevailing official descriptions and regulations concerning the architect's responsibilities no explicit attention is paid to the task of designing the design process. However, just like any other artefact, design processes have to be designed.
Next to the mere building design activities, the design process comprises preparation of the brief (the functional building design) and process design. The architectural design process is part of the complete building process which, next to design and construction, consists of phases of use and management, adaptation and demolition.
In designing the constituent phases of the design process it is important to consider them in relation with all other phases of the building process, as their contents are contributory to the content of the design process and therefore they should be anticipated. Traditionally, all kinds of tasks have been combined in historically, socially and culturally determined roles of participants. These traditional patterns tend to fix positions and to limit possibilities for the introduction of new design strategies.
This observation regards a trajectory of design processes on the level of the complete life span of a building. On the level of a project, design processes consist of serial and parallel connected activities; serial activities take place in a sequence of phases, parallel activities take place simultaneously in so called concurrent engineering or design.
Concurrent design is in comparison to traditional processes characterised by a shift in emphasis from serially linked design tasks to parallel performed tasks. For serious reasons the concept of concurrent engineering is introduced in modern industry. This does not only concern production, but also design. For example, in the aircraft industry there are nowadays design teams consisting of over a thousand designers working at the same time at the design of one new aeroplane. Only a few reasons for this approach are:

- To attain a shorter time-to-market from a first new idea up to a successful new product on the market, especially in those branches with strong competition in order to achieve a higher efficiency and better cost control: the best product for the lowest price.
- To cope with the revolutionary increasing complexity of new technological products, in which designers and manufacturers of a wide variety of high specialisations work together; in this way the creativity and craftsmanship of numerous specialists of very different disciplines can be used for the design of new products.

These issues are also of importance for the building industry and for modern architectural design tasks, which tend to become more complex and are increasingly characterised by collaboration of a variety of different designers and the participation of all kinds of participants.

The design of design processes has become an important issue. A major problem is how to design such processes and projects, how to organise and manage them. How should all the partial design tasks be defined and co-ordinated, how should such vast design teams be organised and how should all partial design results be integrated into a definitive overall design?
In order to provide a conceptual framework for concurrent design we have tried to describe design tasks and parties in a design process separately, so that they may recombined in the end in such a way that optimal configurations for a concurrent design strategy can be found, depending on the specific demands and circumstances of specific projects (Bax and Trum 1996).
In this approach the definition of properties of artefacts (the objects to be designed), design tasks, their articulation and demarcation, their interfaces and the assignment to various designing and decision-making parties in different phases of design projects is emphasised.
In this paper a model of the design process is devised and described. This (general) model can - through confrontation with the project context - be transformed into a (specific) process plan. The process model is useful for analysis and evaluation of existing or already completed processes, as well as for synthesis of processes to be designed. By using the same model in subsequent projects it is possible to gain knowledge and experience from earlier projects and re-use it in the design of new processes.

3.1.1 Domain Theory

Domain Theory (Bax 1979; Trum 1979; Bax 1989; Trum and Bax 1992; Bax, Trum and Nauta 2000) is applied as the theoretical reference for the development of the process model. This theory yields a general design framework describing objects and processes in the field of technological design (Trum and Bax 1990). The theory, which originates from the building design field, is an elaboration of General Systems Theory in the field of technological design. Designed objects as well as objects under design are considered systems, containing sub-systems (hierarchical, aspect- and phase-subsystems) and their elements.

3.1.2 GOM-model

The framework comprises a number of descriptive models, of which the Form-Function-Time model (the so-called GOM model, Figure 3.1) is the most important. This model considers form, function and time as three dimensions of any artificial object. This means that an object is always - independent from its stage of development – defined by its form, function and time properties. The three dimensions, depicted on the x-, y- and z-axis, are articulated in terms of formal scales, functional domains and temporal states of the object respectively.

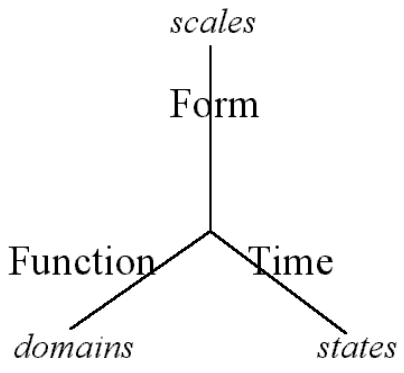

Figure 3.1: GOM-model: Object model of architectural object in statu nascendi.

3.1.3 Concept model

The Concept model – an other descriptive model in Domain Theory – is a taxonomy (Bax and Trum 1993) representing an object as a notional and imaginary object with both an instrumental and a symbolic meaning. Its specific properties make the concept legible and understandable to people who share the same culture; its general properties make the concept applicable to a range of situations. A concept arises in the designers' mind at the beginning of each phase in design in any (partial) design field and directs his or hers thinking and action. Concepts have structural properties, enabling the generation of variant objects (as plans) when confronted with a context.

The Taxonomy of Concepts completely and consistently describes all aspects relevant to a (disciplinary) design situation, arranged into three levels of concepts (Figure 3.2). This arrangement does not imply the order they are dealt with in a phased process. Each concept is represented as a GOM-model, putting emphasis on the functional dimension of the object. In the taxonomy the concepts are ordered according to this dimension.

Policy Concept		
Artistic Concept 'symbol' (intelligibility)	*Scientific Concept* 'model' (testability)	*Professional Concept* 'partitura' (organisability)
Planning Concept		
Physical Concept 'building' (conceivability)	*Economic Concept* 'capital' (payability)	*Social Concept* 'territory' (manageability)
Design Concept		
Constructional Concept 'installation' (tenability)	*Technical Concept* 'work' (makability)	*Use Concept* 'facility' (usability)

Figure 3.2: Taxonomy of Concepts

In Domain Theory an architectural design is the result of a process in which, according to the GOM-model, three types of partial designs are integrated. This means that a formal, a functional and a temporal design are integrated in the overall design. A formal design in architecture emphasises the morphological aspects, articulated in scales; a functional design focuses on the functional aspects corresponding to the Concept-model, and a temporal design stresses the procedural aspects, reflecting the organisation and the procedure within a project. So, the three dimensions of the GOM-model constitute three fields of design, which have a relative autonomy, though co-ordinated in the GOM-model. These observations are valid for an architectural object, but they are valid too for each object which is subject of a design process: e.g. an organisational object (Van Aken 2001) and a process object, which together with the architectural object, form the constituent partial objects or designs of a project.

A formal architectural design is a configuration of spatial elements, together with its syntactic rules of composition.

A functional architectural design is a list of rules and norms, expressing quality, in the formulation of a brief or program of requirements, related to elements of the formal design.

A temporal architectural design relates the formal and functional elements of their corresponding designs to parties and activities of a design procedure in terms of time.

So, formal, functional and temporal design are ordered in a hierarchy of presumption or actual decision making within the framework of the GOM-model. They are defined in an interrelational way; this means that e.g. a functional design, just like any other design, has formal, functional and temporal aspects. However, in a functional design, the emphasis is on the functional aspects, based on formal presumptions within the perspective of future developments by mandated parties.

3.1.4 Outline of the process model development

For the development of the process model the following pairs of subjects are analysed equivalently and analogously: objects and processes; architectural and organisational objects; programme and situation.
The following conditions are applied for the achievement of synthesis: model-plan-cycle in the development of objects; matching of functions of architectural and organisational objects according to concepts and matching of the forms of these objects according to levels; matching of contents of levels (of architectural and organisational objects) and phases.
For the process model development the following phasing is applied: identification or initiative phase; definition or model phase; specification or plan phase.

3.2 Objects and Processes

Projects concern the development of both objects and processes. Objects and processes are considered both subjects and results of (distinct, but similar) design processes. In Domain Theory, objects and processes are described principally in terms of the same categories. This means that the description method of objects also applies to processes. Objects under development are described in terms of their *state* at any time in the process. A relatively stable and temporary state is denoted as a stadium or *stage* of the object. Processes are composed of phases and phases are composed of serially or parallel connected activities. Stages of an object correspond with phases of a process. The term stage mediates between the state of an object and the phase of a process; a stage is the expression of the state of an object in terms of its place in a process. During its development the object passes through several intermediate stages and in each stage it is in a particular intermediate state. States, stages and activities are entities characterised by size, place and quality within a system: an object system or a process system. The process system is of a higher order than the object system: formally, the process comprises the objects. Because of the formal characteristics of its elements, the process system is considered to be an object-system, and as a consequence processes are represented in the GOM-model in the same way as objects.

3.3 Architectural and organisational objects

Both architectural and organisational objects are described according to the same general design framework provided by Domain Theory. The framework comprises a taxonomy of concepts, which provides a ‘format’ to the designer that enables him to completely, consistently and transparently describe a relatively autonomous design situation, without the necessity to go into the territory of other designing disciplines. The taxonomy is supposed to be valid for all designing disciplines, for all levels and for all phases and steps in the design process.
In the architectural design discipline, concepts enable attachment of attributes to physical/spatial elements, yielding several (sub) systems that correspond with the concepts.

In the organisational design discipline, the same concepts are supposed to enable attachment of attributes to organisational elements, yielding several (sub) systems corresponding with the concepts.
The necessity of co-ordination of the design situation within a project involves a seemingly overlap between the descriptions made by designers of diverse disciplines, in this case the architectural and the organisational discipline. This image is evoked mainly by the fact that both types of designers make use of the same concepts. This overlap however, is just apparent, as architectural descriptions concern architectural objects with among others organisational attributes and organisational descriptions refer to organisational objects with among others architectural attributes. The overlap of both types of descriptions determines the field of interaction and iteration between the design of architectural and organisational objects. An example may clarify this.
During the design of the architectural object decisions are made that emerge from its socio-political context in terms of descriptions according to the Professional Concept, the Use Concept, the Social Concept and the Technical Concept. They involve manipulation of the architectural object by the designing organisation, the organisation to be accommodated, the managing organisation and the production organisation. Designing the organisational object involves manipulation of the organisational object by the physical/spatial context. For this reason the architectural and the organisational object ought to be designed simultaneously and interactively. This means that the dimensions and articulations of both, architectural and organisational objects have to be adapted, 'tuned' or 'matched' to each other. Though all mentioned types of organisation are relevant, the process model emphasises the designing organisation. In the Professional Concept of the architectural object, the articulations i.e. subsystems of the physical/spatial design, are provided with attributes derived from the design of the designing organisation. That is, for groups of elements it is determined which parties have which mandates. Thus, the building is represented in terms of design tasks.
The organisational discipline is a special discipline, insofar that it is involved in the design of all kinds of artefacts, and thus in all branches of technological design, whether of an architectural, mechanical, information-technical, etc., nature. Though not further elaborated here, is it argued that multidisciplinary design with more than the two disciplines mentioned above passes off in a similar way.
In the description of a design situation, the concepts of the taxonomy do not only deal with potentially synchronously designing disciplines, but also disciplines acting in successive phases are involved. For example, the Social and the Technical Concept anticipate decisions to be made on a more detailed level in future phases of the total building process. This means that these decisions in the design stage - the subject of the model under consideration - should be structural: they should establish things as well as leave space for future decision making. In the construction and management phase of the building process the parties involved will perform decisive roles, whereas in the design phase they have a limited mandate, for instance as advisors.
In general, it does not matter whether actual parties are involved consisting of actors, or factors that influence the design. It is possible to depict the whole process as a process of actors as well as of factors. Factors or actors cover the whole field of design. Factors determine not further dividable forces of influence on a certain level of specialisation. The number of actors is equal to or smaller than the number of factors; in an extreme case one actor can fulfil all factors. It is the mere objective of designing a designing organisation to decide which actors have to be distinguished and which factors they have the mandate to decide about.

As the taxonomy implicates the contents of other (functional) disciplines and of other phases in the phase in which the actual designer is at work, a complete and practicable design situation can be described in terms of the three object dimensions of Form, Function and Time.

3.4 Situation and programme

All phases of the design process concern the design of an object based on the interaction between the requirements from the programme and the requirements of the (existing) situation, which are brought to synthesis in a plan. The situation is that particular part of the context of the project that has already been decided about (in a former process or in a former phase of the same process) and therefore can not be changed or influenced by the designer. In fact, the situation is the complete set of constraints, i.e. all starting points and limiting conditions, if possible translated into verifiable criteria.
As to form, function and time, the object to be designed will have to fit into this situation. This fit takes shape in a process; a basically never-ending process, as continuously adaptations will turn out to be necessary. This applies to the design as well as to the surrendered building. In a snapshot in time of that process a synthesis of a formal and a functional design may be perceived. In the early stages of the process the functional design dominates, while in later stages the formal design prevails. A complete and well-structured brief is an example of a functional design; a complete and well-structured situation is an example of a formal design. Moreover, in principle a programme always has a form-dimension too, and a situation always has a function-dimension.

3.5 Model-plan cycle

A model of an object is a structural representation of reality; it is simultaneously a conceptual system of meaningful elements, a conceptual system of qualitative norms and a conceptual system of rules by which material, sensory perceptible variants can be generated. This phenomenon occurs when the (abstract) model is confronted with a (concrete) context. Even in the case of structural description, just like in any object, a formal, functional and temporal dimension occurs. Any concept interpreted as an object, defines a corresponding aspect system, of which both the model description and the plan description are possible. The total object is thereby considered a mergence of several systems within the boundaries of the object.
A plan appears as follows: The plan is a choice from a set of plan-variants generated by the model. In a more complex design situation several (partial) models of the object to be designed generate, whether or not simultaneously, several sets of plan variants. In such a case first the mathematical cross-section of the sets should be determined, from which a selection can be made.
The transformation from model into plan may occur several times in a process. This means that a plan can be interpreted as a model again, which can be worked out into a plan. The principle of transformation from model into plan, from plan into (a more specified) model and then again from model into (a more specified) plan, indicates, because of the double role of the plan, a level-transition. The principle is applied in describing the whole design process, in a sequence of phases. The principle is also applied within a phase, where analysis of programme and situation results in two models that produce an integrated plan by means of synthesis.
The principle of plan making interpreted as a confrontation of a model with a context, or as a confrontation of two models, is a way of representing the hardly fathomable process of

synthesis. In that, the design approach according to the so-called conflict model is chosen, in which the eventual design is considered a reconciliation of incompatibilities.

3.6 Match of levels, functions and phases

Activities are characterised by their position and duration in a design process. Activities can be connected in series or in parallel. Within an activity synthesis of architectural and organisational objects is performed. This means that parties of a designing organisation have the task to make decisions about elements of architectural systems. In order to establish this synthesis, a linking should be made of the diverse dimensions determining these parties and elements in an activity.

In accordance with the theory, architectural as well as organisational objects have a functional dimension, i.e. the elements of the systems to which they belong, have functional attributes defined by the concepts of the taxonomy. Architectural objects have properties of physical/spatial elements; organisational objects (groups and parties of a designing organisation) possess knowledge about these properties. By using the same concepts of the taxonomy a functional linking occurs, a 'match' between architectural and organisational objects, in which the architectural object is also defined by the organisational object and vice versa. Application of one and the same taxonomy is compulsory for this match.

A second condition for synthesis is a match of levels of architectural objects organisational objects. Both kinds of objects have an articulation in levels. According to the conventions of the GOM-model a design space is represented by a cube with three dimensions: Form, Function and Time. A designer finds him/herself in the middle of this space and has 2 x 3 orientation possibilities: up and down, left and right, front and back The position of the designer is determined by dividing every dimension of the model in three parts; more divisions are not needed for this view. This means that the Form dimension is subdivided into three levels, the Function dimension into three domains and the Time dimension into three stages of development. There are only three domains (Usability, Tenability and Makability), but more levels and stages are conceivable. The presence of a middle level enables the consideration of its relation with a higher and a lower level; a stage may be considered in relation with its preceding and following stage and a domain may be considered in relation with its adjacent domains. Thus, all occurring relations can be represented schematically.

In this way the original single cube is subdivided into three 'tranches' representing level-bound design spaces, three 'tranches' representing domain-bound design spaces and three 'tranches' representing stage-bound design spaces (Figure 3.3).

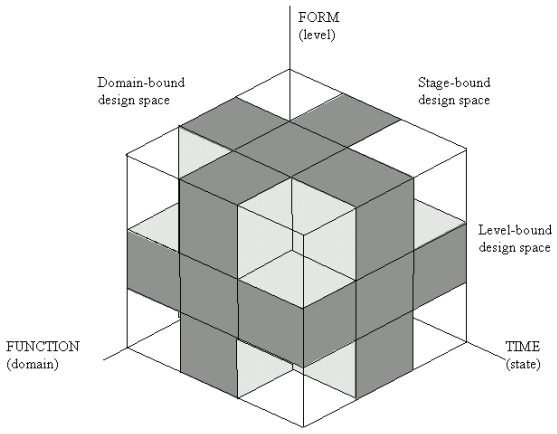

Figure 3.3: Design spaces of architectural and organisational objects according to Domain Theory.

The upright standing functional design space is sliced horizontally by three level-bound design spaces and vertically by three stage-bound design spaces. According to Domain Theory not only forms are articulated in levels, but functions too. These are specification levels as e.g. described by (Jones 1992) in his chapter about Specification Writing. As for the aforementioned bridging function of the functional dimension of architectural and organisational objects, identical articulation of the levels (of the form dimension) of both kinds of objects through the articulations of the functional dimension, is essential. This tuning is called 'matching levels'.

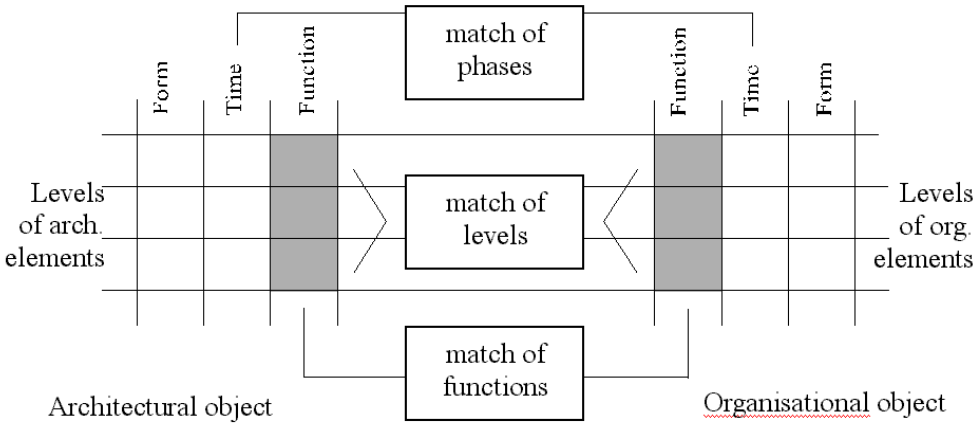

Figure 3.4: Match of levels, functions and phases. The principle of both types of matching is represented. The three dimensions of the architectural and the organisational object are depicted as three parallel (communicating) columns with the contents of Form, Function and Time.

The result of matching of functions and levels is that physical/spatial elements are arranged in levels, both in a formal and a functional sense, corresponding with organisational elements being authorised thereto.
In designing architectural design processes it is useful to join in with the traditions of the architectural discipline, i.e. that physical/spatial levels correspond with usual drawing scales. The articulation of the object's formal dimension is dominant with respect to the articulation of the functional dimension and also dominant with respect to the articulations of the organisational object.
If these conditions are fulfilled, the move may be made from objects to processes. The contents of the levels of the objects are then put on the same footing as the contents of the articulations of the design process, the phases. Next to the match of functions and levels, a match is made between the time dimensions of the architectural and the organisational object. The authorisation or mandate of each party is determined for each stage of the object. With this last step of matching phases, all dimensions of both objects have been tuned.

3.7 Processes and Activities

The design process consists of phases and phases consist of activities, which again may be composed of sub-activities. Activities may be considered the elements of the system; in this case not an object system, but a process system. There is no fundamental difference between phases and activities, although within a phase there is feedback between activities, which means that the result of an activity may have a preliminary and temporary status, while the result of a phase principally has a definitive status.

The contents of an activity is determined by a set of physical/spatial elements, their functional features and the parties deciding about them. As the activity is a building stone of a process, an activity is also characterised by an 'input' and an 'output', or an initial situation and a final situation. Moreover, management, monitoring and evaluation of all occurring manipulations should be carried out, in which prevailing rules, regulations and norms are taken into account. These subjects are also referred to as 'controls' of the activity. Next, the process should be provided with instruments, tools and resources, necessary for the execution of the operations; often somewhat deceivingly referred to as 'mechanisms'. According to the IDEF0 method input, controls and mechanisms can be output of other activities in an overall approach of the total design process. Again, output can be input for other activities and numerous feedback loops can be observed in the process. Activities can be split up into sub-activities, etc. (IDEF0 1993).
Pairing parties and physical/spatial elements determines the parties' mandates. Furthermore, in a process it is necessary (insofar the 'mechanisms' do not provide such) to determine the period within which the activity should be completed, the position of the activity in the course of the design process and the budget available for carrying out the process.
A phase consists of a number of activities, partially or completely connected in parallel or in series. The design process in principle proceeds from global to specific; i.e. from a low towards a high degree of specification. The contents of a phase consists of activities in which decisions are made about physical/spatial elements belonging to the same level. These decisions are made by parties assigned to a corresponding organisational level. Thus a direct relation exists between the contents of levels and phases, though levels primarily relate to objects and phases apply to the articulation of a process. Therefore, in designing the design process the resulting process phasing should be taken into account already in the first phases of that process, when levels are discerned.
In designing the design process fundamentally the same categories are used as in the design of objects: here programmes and situations, models and plans are involved too, although these categories now apply to a process and therefore concern activities establishing this process.

3.8 Design process: strategic choices

Though in the design process model several ways of phasing are conceivable, in this model a sequence is chosen in which successively an initiative-phase, a model- and a plan-phase are distinguished. These phases roughly correspond to the identification-, definition- and specification-phase as mentioned in the introduction. In each phase the architectural object, the organisational object and the design process are involved. Within these phases a sequence of programme and situation, model and plan sub-phases is discerned. In all (sub-)phases partial processes and feedback may take place simultaneously.

- In the identification or initiative phase (of the design of the design process) descriptions are made on a typological level. At this level the difference between the formal, functional and temporal dimensions of the object fades away, and the object is considered primarily as an entirety, as an image with its symbolically loaded meaning. Architectural as well as organisational objects and processes are considered as types.
- In the definition or model phase (of the design of the design process) descriptions are made on a systems level. At this level the form, function and time dimensions of the elements (objects and activities) are distinguished. This phase focuses on modelling the object and articulating it into levels.

- In the specification or plan phase (of the design of the design process) descriptions on a detailed level are made of the organisational object (the designing organisation) and the design process, aimed at the implementation of the design process. The object that was modelled in the previous phase, is now transformed into an object plan.

Specification of the architectural object takes place during the implementation of the designed process; this matter is beyond the scope of this discussion.

3.9 Design process model

Within the chosen strategy and based on the discerned categories: objects and processes, architectural and organisational objects, situation and programme, model and plan, it is now possible to describe a model of the design process in broad outline (Figure 3.5).

3.10 Design process as a plan

3.10.1 Identification phase

Identification of the kind of architectural of object
Global description of the requirements (and possibilities) of the programme and the situation. The description is made on a typological level (e.g. a regional hospital with 100 beds in the centre of a medium-sized town, a pavilion building type, etc.).

Identification of the kind of organisational object.
By analogy with the categories of the identification of the architectural object.

Identification of the design process
Global description of the requirements (and possibilities) of the programme and the situation. The description is made on a typological level (e.g. a serial or a parallel process, etc.).

3.10.2 Definition phase

The identified project is defined by modelling objects and processes according to a general description model.

Definition of the architectural object
Detailed description of the requirements and possibilities of the programme and the situation. Because of the heavy interaction between the two categories of requirements, no further systematic distinction into sub-phases is made here. The description is made on the basis of a structured analysis according to the description model of Domain Theory. Formal, functional and temporal dimensions of objects are described in qualitative and quantitative terms. Within the discerned (formal) spatial levels (and phases to be coupled eventually thereto) the analysis is carried out according to the (functional) concepts of the taxonomy. The analysis primarily concerns distinction of levels and subsequently decisions about the assignment of (functional) attributes to physical/spatial elements of the architectural object. Through this the identified object is defined and modelled. It should be reminded that the object is primarily determined as a functional design. This phase is concluded with synthesis of the analyses (of programme and situation) in a schematic model, articulated in levels.

Definition of the designing organisation (as an object model)
By analogy with the categories of the definition of the architectural object. This phase is concluded with a schematic model, articulated in levels, defining the mandates of the parties involved: the position structure.

Identification phase (Initiative phase) of the design process
1) Identification of type of architectural object. 2) Identification of type of (designing) organisation. 3) Identification of type of design process.
Definition phase (Model phase) of the design process
4) Definition of the architectural object (as object model) • Programme analysis. • Situation analysis. • Synthesis into a model of the object. 5) Definition of the (designing) organisation (as object model) • Programme analysis. • Situation analysis. • Synthesis into a model of the organisation. 6) Definition of the design process (as process model) • Programme analysis. • Situation analysis. • Synthesis into a model of the process.
Specification phase (Plan phase) of the design process
7) Specification of the designing organisation (as object plan). 8) Specification of the design process (as process plan).

Figure 3.5: Design Process Model

The architectural object to be designed and the organisational object to be designed mutually define each other. Several options arise: the architectural object imposes an organisational situation, or the opposite; adaptations are made on both sides. In the latter (most common) case iteration takes place. This iteration ends if a match is achieved of the functions and levels of the architectural and organisational object.

Definition of the design process (as a process model)

The definition is a further specification of the process type from the initiative phase. Based on the definition of the already functionally and formally tuned architectural and organisational objects (physical/spatial elements and positioned parties) activities are defined and arranged in the phasing of an architectural design process. To the design of the process as a model the same rules apply as to the design of objects. Hence there is a process situation and a process programme in terms of mandates, budgets and time limits. Thus a process model is defined

that is still open with respect to specification into a process plan in the specification or plan phase. This plan is a further specification and interpretation of the model.

3.10.3 Specification phase (plan phase)

Specification of the designing organisation
This concerns principally filling in the names of agencies and bodies belonging to the designing organisation and the detailed regulation of their mutual relations.

Specification of the design process
The model of the design process is filled in. Activities are architecturally and organisationally specified. This means that architectural elements are named, that intended changes are determined and that is decided which parties have which mandate to perform this task. The input, output, controls and mechanisms of the activities and the phases of the process are determined (e.g. according to the IDEF0-conventions). Also time limits and development budgets are laid down.

3.10.4 Implementation

After the design process is specified the implementation of the design process may be started. During this process the architectural object model is specified into an architectural object plan.

3.11 References

Aken, J. E. van (2001). Domain-Independent Design Theory, in: Achten, H. and Vries, B. de and Hennessey, J. (eds.) *Design Research in the Netherlands 2000*, Eindhoven University of Technology, Eindhoven, pp. 9-17.

Bax, M.F.Th. (1979). Domain Theory, Scope and Structure of Building Science, *Open House*, **3**, pp. 30-43.

Bax, M.F.Th. (1989). Structuring Architectural Design Processes, *Open House*, **14**, pp. 20-27.

Bax, M.F.Th. and Trum, H.M.G.J. (1993). A Taxonomy of Concepts in Architecture: A New Tool for Analysis and Synthesis in Architectural Design Processes According to Domain Theory, in: Behesthi, M.R. and Zreik, K. (eds.): *Advanced Technologies; Proceedings Fourth EuropIA International Conference on the Application of Artificial Intelligence, Robotics and Image Processing to Architecture, Building Engineering, Urban Design and Urban Planning*, Elsevier, Amsterdam, pp. 53-64.

Bax, M.F.Th., and H.M.G.J. Trum, (1996). A Conceptual Model for Concurrent Engineering in Building Design according to Domain Theory, in: Timmermans, H. (ed.) *Proceedings 3rd Design and Decision Support Systems (DDSS) in Architecture and Urban Planning Conference, Spa, Belgium, Part 1, Architecture Proceedings*, pp. 527-546.

Bax, M.F.Th., H.M.G.J. Trum and D. Nauta jr. (2000). Implications of the Philosophy of Ch.S. Peirce for Interdisciplinary Design – Developments in Domain Theory, in Timmermans, H. (ed.) *Proceedings Design Decision Support Systems in Architecture*, Nijkerk, 2000.

IDEF0, 1993, *Integration Definition for Function Modeling*, Federal Information Processing Standards Publications, National Institute of Standards and Technology, Gaithersburg, USA.

Jones, J.Ch. (1992). *Design Methods*, 2nd ed. Van Nostrand Reinhold, New York.

Trum, H.M.G.J. (1979). *Over het Normbegrip in de Bouwkunde*, Ph.D. thesis, Technische Hogeschool Eindhoven, Eindhoven.

Trum, H.M.G.J. and M.F.Th. Bax (1990). The Applicability of Domain Theory in Technological Design, in: McCabe, V.J. (ed.) *Design in Engineering Education, Proc. SEFI Conference*, Dublin, pp. 397-402.