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Design Configuration with Architectural Objects

A Platform Organization Model for Industrialized House-Building

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Abstract. *The paper presents the intermediate results of an ongoing research project with the aim to develop concepts and tools for architectural design in industrialized house-building. Architectural design aims to enable different “situations” in the built environment involving people, behaviour, experience and environment, with desired technical, functional and aesthetic properties. “Situations” may be represented by configurable modular “architectural objects” that also reflect the variability of an industrialized building system. In three case studies the relevance of the concept of architectural object is investigated; in architectural design, and through modularization, development and organization of technical platforms. The results however also show a need for further research concerning the implementation in a BIM environment.*

Keywords. *Architectural object; Situation; Design configuration; Industrialised house-building; BIM.*

INTRODUCTION

The paper presents the intermediate results of an ongoing research project with the aim to develop concepts and tools for architectural design in industrialized house-building. Industrialized house-building in this context refers to an efficiently managed construction process using highly developed off-site manufactured modularized technical-functional house-building components or modules. Development of an industrialised building system is done separately from application of the system in various building projects (Lessing 2006). Building design is seen as a process of configuration where variable or interchangeable parts of the technical platform are determined (Hvam et al. 2008).

Architectural design deals with a problem complex that besides technical aspects also

concerns user functionality and aesthetics. During a traditional design process the architects have a central role in coordinating different requirements concerning use and construction. This is often done in an iterative process defining problems and solutions in parallel. This approach is however not suited for the special bi-folded design process in industrialised house-building, where product development is separated from project design.

In design practice the configuration system for a technical platform contains information about the platform's technical parts and the restrictions for design (Olofsson et al. 2004). The configuration system normally does not include information about functional parts, e.g. furniture or activity spaces, or

aesthetical properties of different solutions. This information is supposed to be handled independently by the designer. However, if information about user activities and aesthetics could be included and handled by the configuration system the architect would be able to work with more complete configuration modules representing whole architectural "situations".

The research reported here is part of a larger project that aims to investigate research questions in three areas of importance for industrialised house-building:

- How are the preconditions for architectural design affected in product development?
- How can the processes be organised to facilitate architectural design?
- How can the information be organised to facilitate architectural design?

THEORY

Architectural design does not only affect the built environment but also intentionally affects the humans who use and experience it (Steadman 1979; Hillier 1996). The built environment sets conditions and gives possibilities for human activity; therefore it is relevant to conclude that architectural design handles man and building as a socio-technical system (Ekholm 1987).

The environmental psychologist Roger Barker has introduced the concept "behaviour setting" to refer to a concrete unit of behaviour and milieu, with "the milieu circumjacent and synomorphic to the behaviour" (Barker 1968). According to Amos Rapoport "the environment can be conceptualized as a system of settings within which a system of activities take place" (1997).

Christopher Alexander's similar concept "pattern" is described as a design unit with a strong emotional content referring to concrete systems of place and human activities and experience (1977). The inseparable unit of social activity and built environment is named "fabric" by John Habraken in a similar attempt to capture the essence of the built environment in use, as a living organism (2005).

The built environment is generally thought of as organized in different levels of design or "intervention" (Habraken 1982, 1998; Ekholm 1987). The level order reflects both the artefacts' size and other aspects, and how they are controlled in different levels of social systems. Based on this insight, the Swedish National Board of Public Building identified three levels of building parts: society related, building related and organization or activity related parts (Ahrbom 1980). Based on the analyses above, the level order of socio-technical systems regarding control of the built environment in a building design context consists of four main control levels. See Table 1.

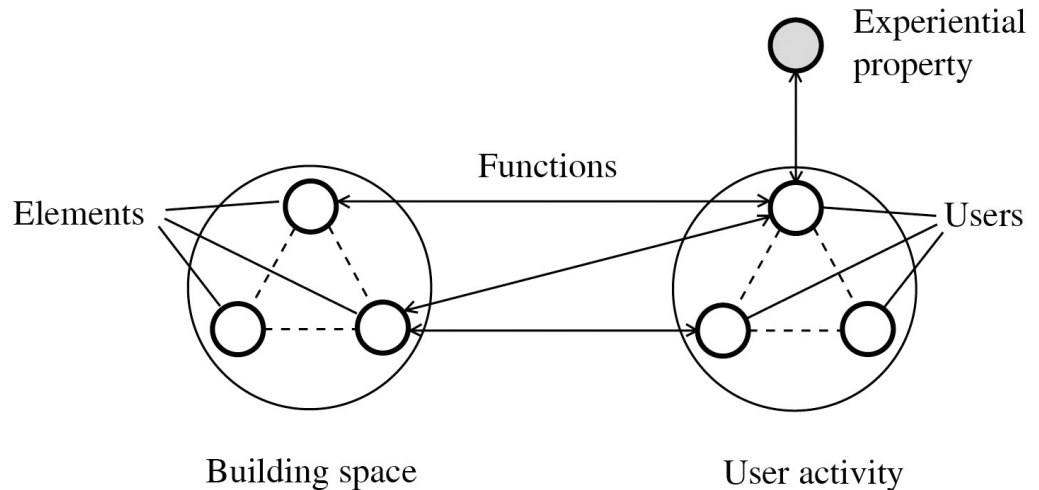
Hypotheses

The ideas of "behaviour setting" (Barker 1968), "pattern" (Alexander 1979) and "fabric" (Habraken 2005), comprise the background of our concept "situation", which refers to units of people, behaviour, experience and built environment. In the context of object-oriented architectural design software, a "situation" can be represented as an "architectural object", referring to real situations of people, behavior, experience and environment as a unit. Phenomenal properties must be attached to this whole scene. See Fig.1.

Control actor	Controlled built environment	Control level
City authority	Infrastructure (streets, sewer etc)	City, neighborhood
Building management	Building related building elements	Building
Building user organization	Organization related building elements	User organization space
Building user	Activity related building elements	Activity space

Table 1.
Levels of control, built elements, and actors in the system man-built environment.

Figure 1.
Constituents of an architectural object



A primary hypothesis in the project is that the concept of architectural object could be a support for architectural design in industrialized house-building. An architectural object may be modularized and parametric and part of a configuration system and composed of parts of the building system and user activities, e.g. furniture and activity spaces. Architectural objects may also be organized in design levels reflecting the control levels that are expressed in the composition of situations earlier observed in the built environment. The hypothesis however calls for a reformulation of the research questions in order to include the concept of architectural object. The revised research questions are therefore formulated accordingly:

- How can architectural objects be a support for the organization of product platforms, and project related information, to facilitate architectural design in the processes?
- How can a level structure of architectural objects support the design configuration process from an architectural point of view?
- How can the preconditions for architectural design benefit from implementing the concept of architectural objects in product development?

METHOD

The pre-conditions for supporting architectural design in industrialised house-building using the concept of architectural object were examined from different perspectives. Three case studies were designed and conducted at two companies with different modularization strategies concerning the technical platform.

The first case study

The first case study was partly conducted as a bench-marking survey to document the present architectural design methodology and the information processes of a company involved in industrialised house-building. The studied company Open House Production AB, Sweden, was specialised in producing multi-family housing based on volume elements. During its 5 year house-building operation about 1500 apartments was finished in Oslo Norway and the Swedish Malmo region.

The introductory part of the study recognized that the company architects' product models were built up from their own volumetric design modules rather than objects reflecting technical components or modules in the technical platform. These design

modules, besides dealing with the technical aspects, implicitly included a model of user activities and phenomenal properties of the built environment. Consequently, the architect's conceived platform could better support the design process, where a comprehensive architectural view is needed to handle the complete set of project requirements including a customer focus. This observation supported the relevance of the concept of architectural object.

In the main part of the study the concept of architectural object was analyzed as support to the modularization of the technical platform. This was made on the bases of a realized project. The purpose was to define a selection of configurable architectural objects that reflect the variability of situations effective in that project, and possible to achieve using the company's house-building system.

As a result of the case study it was shown possible to include the technical platform objects as parts of different architectural objects. Related information concerning user activities and phenomenal properties could also be conceived as included in these architectural objects. From this point of view architectural related information was shown

possible to handle in a comprehensive way according to these objects. The derived objects were developed as modularized parts of a product platform (see Fig. 2), possible to use in other projects. In an industrialized house-building process including volume elements, architectural objects could be developed during the product development phase and applied during building project design as configurable design units.

The experience of the case project shows that industrialized house-building need not take the technical systems solely as starting point for modularization and configuration, if presented with this alternative concept. If architectural design could be supported by predefined architectural objects, then deviations from the platform could easier be avoided in the design process. The information can be made accessible to all parties in the design, production and facilities management processes as part of a BIM environment.

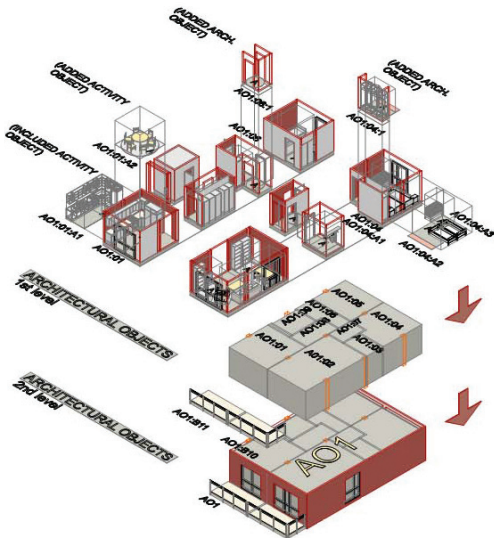
The results from this case was further dealt with in a conference paper (Ekholm and Wikberg 2008).

The second case study

The second case study was mainly experimental, and used complementary project data received from the same company as studied earlier. The case investigated the possible support of architectural objects in the design configuration process, using the Open House building system as reference. It explored whether a design process based on architectural objects is feasible and what the advantages would be. The intended benefits in a further development would be a configuration methodology complying not only to a technical systems view, but also with meeting client objectives concerning use and experience.

The case took as a presumption that an already realized block of 56 rental apartments was to be designed using architectural objects as modules of the product platform. The case study tried to back trace the executed design and

Figure 2.
Derived product platform in case 1



simulate how it could have been achieved using a platform transformed into architectural objects. The obtained platform should once again reflect the variability of situations observed in the project, and the limitations effective in the system. Decisions relevant to the design process were considered in relation to control levels in the built environment. On each level of control the client's building program and the industrial house-building system were guiding and restricting the design, but also the master plan and other stakeholders' interests were considered to influence the decision making. Levels of control identified in the case project were the city level, the building level, the apartment level, and the individual activity level, motivating the organization of architectural objects for each of the levels. Still a rather limited number of customizable architectural objects were needed within the range of freedom offered by the system. The outlined process also shows that only four design levels are needed to handle the variation expressed in the studied project.

As a conclusion it was found likely that the concept of architectural object can support a coherent architectural view in the industrialised design process. The results are further described in a conference paper (Wikberg and Ekholm 2009).

The third case study

In the third case study the applicability of the concept of architectural object in product development was analyzed. This urged for additional studies of methods for product and platform development to include these parts in a proposed design process model.

The study was conducted in cooperation with Derome AB, a large actor in timber related business, but fairly new in the industrialised house-building business. Data was jointly collected, with an affiliated research project within the LWE research platform supported by Tyréns AB, a major Swedish AEC consulting company.

The objective was to develop an industrialized house-building platform open to a variety of multi-story housing designs.

The research investigates a method to analyze the results of the development specifically with regard to the flexibility of the platform. The analysis is based on the use of architectural objects as a design interface in different design levels. In the case study, design limitations faced with in a house building system were pin-pointed through performing a functional requirement (FR) analysis of the system parts versus required activity situations in a program, here represented by hypothetical architectural objects. From a functional performance point of view the use of architectural objects as complementary target objects was successful, also giving support to the hypothesis that architectural objects are useful for architectural design in product development. The resulting method is here shown to complement the traditional quality function deployment (QFD) methodology (Aka0 1990) and functional requirement analysis in product and platform development, and shows the relative dependence of design decision levels explored in an earlier paper.

As a result from the study a step-by-step method was proposed:

1. Analysing the requirements on the technical platform.
2. Using the results of a QFD related functional requirement (FR) analysis.
3. Presenting a representative pattern of architectural objects.
4. Testing system related modules against the architectural objects as part of an extended functional relation analysis.
5. Interpreting the output of the matrix, addressing the need for further product development if components or modules are missed out or not up to standard.

A conference paper describes the case results in depth (Wikberg et al. 2009).

RESULT

A platform organization model

In most industrialised house-building systems neither the product platforms nor the technical platforms support a comprehensive architectural view, since the modularity is primarily based on technical building parts. Transparency of a platform from an architectural point of view is therefore hard to achieve. Product platforms with predefined products may however offer this transparency but are generally not adaptable to different demands from a comprehensive view. Market demands for more customized solutions may therefore bring the industry to accept traditional project focused design processes. The proposed platform organization model with architectural objects is an alternative solution, and a first step towards integrating architectural design with a clear customer focus in the industrialized design configuration processes.

Architectural objects are defined as objects

having technical, functional and aesthetic properties, representing real activity situations in a design project. Empiric results have also proven the possibility of modularizing technical platforms according to architectural objects (Ekholm and Wikberg 2008). In the platform organization model situations are represented by configurable architectural objects, where each object may hold variable properties concerning its activity and building elements, and a resulting experiential property (see Fig. 3).

Specific situations may also be formed through including architectural objects, representing parts of situations. The platform model may this way form a hierarchy of enclosure with several composition levels (see Fig. 4).

Composition levels

Most architectural objects on superior levels are expected to hold a number of included architectural objects in lower levels. The model in Fig. 4 instantiates the application of four such composition levels

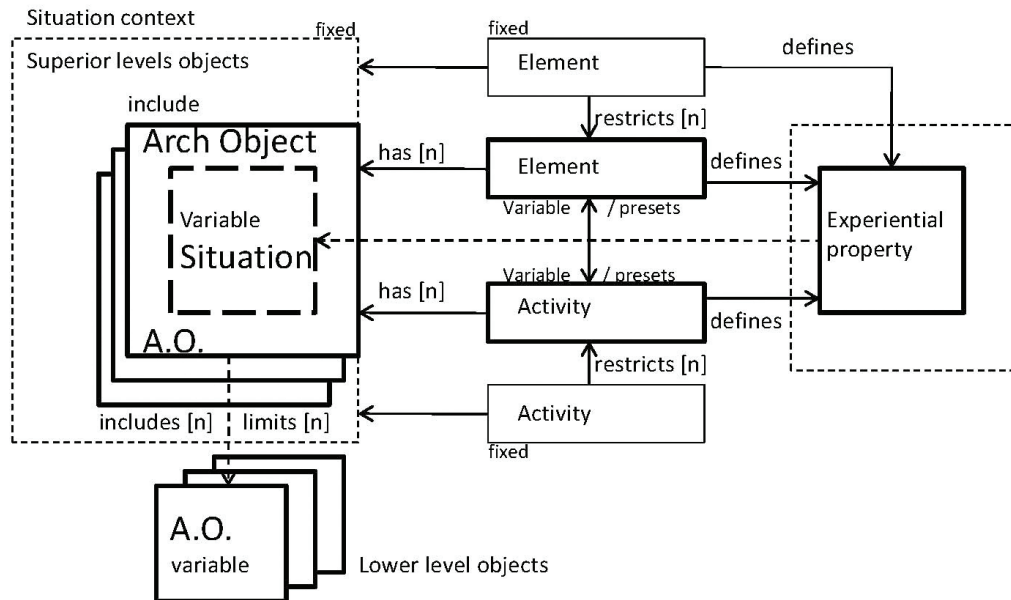


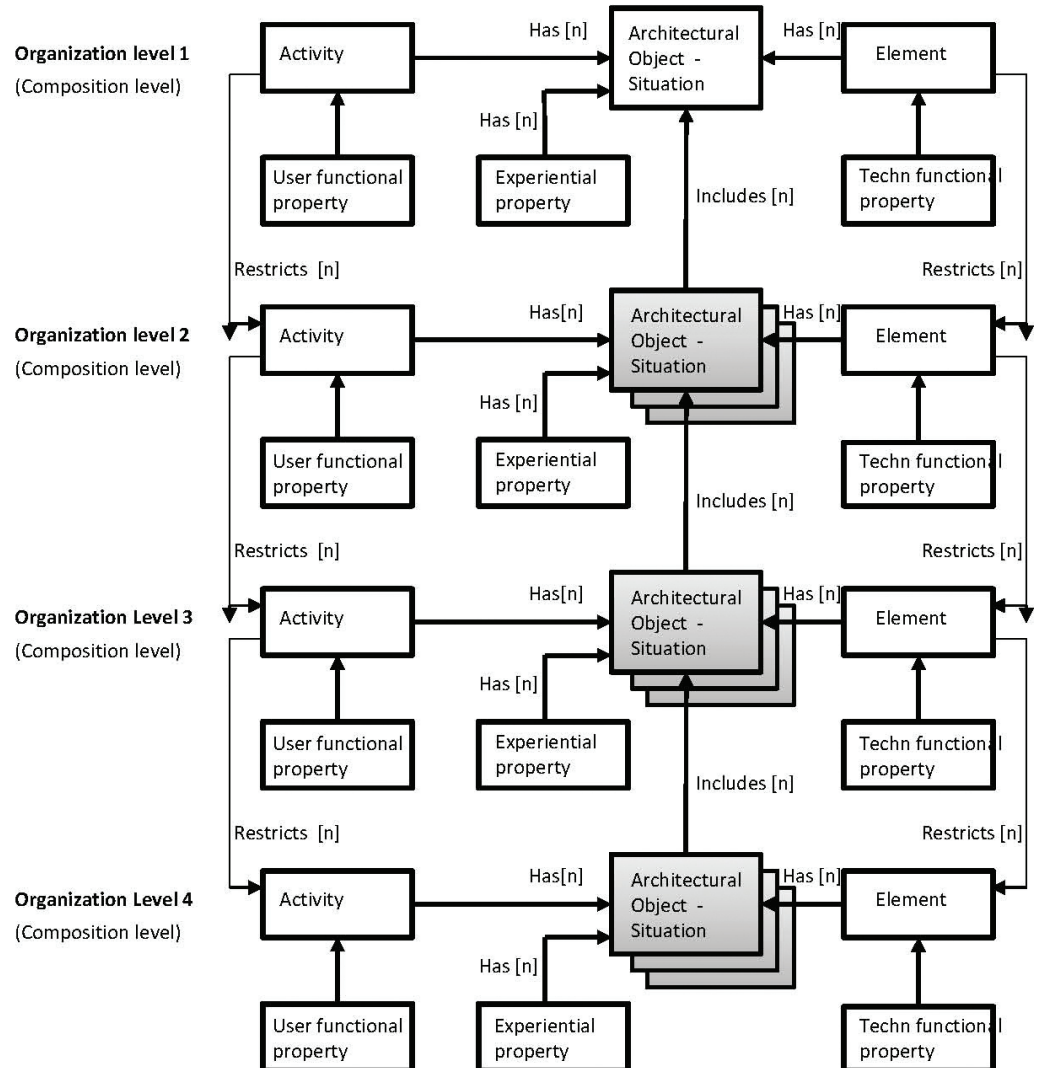
Figure 3. Architectural object properties and dependencies in the platform organization model.

to a platform, even though more or fewer levels may apply. Founded in the theory these composition levels are supported by levels of control in the built environment, where different control actors may control different parts of the built environment. This

is further explored as part of the empiric work (see case study 2).

In a multi-family house design, these four composition levels may refer to the block, the building, the apartment, and the user activity space (see Fig.

Figure 4.
A platform organization model with several composition levels.



5). A positive effect from introducing levels is the reduction of architectural objects needed for specifying particular situations on lower levels. This may also facilitate additional customization options to a product platform from an individual user perspective, as especially objects on lower levels are likely to fit in several superior situation contexts. On the other hand this will inevitably have as a result that the organization of architectural objects in a product platform may form a complex system harder to administrate in the configuration process. This applies when one lower level architectural object specifying e.g. a prefab bathroom situation may fit several superior level situations specifying more generic apartment situations. However, if not open to any variation, these bathrooms may as well be predetermined parts of each of these alternative apartment situations.

Variable object properties

In addition to specifying a design through the level organization, the platform model features the possibility of varying object properties within preset limits of the product platform. Thus each architectural object may from the start have variable properties describing its activity, its elements and its resulting phenomenal properties. The phenomenal properties are dependent on the full situation context and are only perceived by the designer in the very configuration process. When designing a situation this is

made within limits enforced by superior object properties. The model with several illustrated levels (see Fig. 5) shows that activities determined on a superior level this way may restrict possible activities on a lower level. The same applies to building elements. This way, for example exterior walls, load bearing walls and fire walls on a building space level may impose certain limits on the user organization space level for placing windows, entrances and partition walls in an apartment. Altogether the alternatives for varying included properties in an architectural object depend on the options given in platform development. Examples of included properties eligible for variation on a user organization space level is depicted below (see Fig. 6). Dependency relations in the created situation are shown in accordance with the initial model illustrations (see Fig. 3 and 4).

DISCUSSION

The research question how architectural design information, or specifically architectural objects, can be represented in CAD software has only been dealt with principally in the case studies, and will be part of the further development work in the research project.

Implemented in industrialized house-building, a design methodology including architectural objects should support issues of both multi-disciplinary collaboration and user participation in the design process. To over-bridge these issues is often

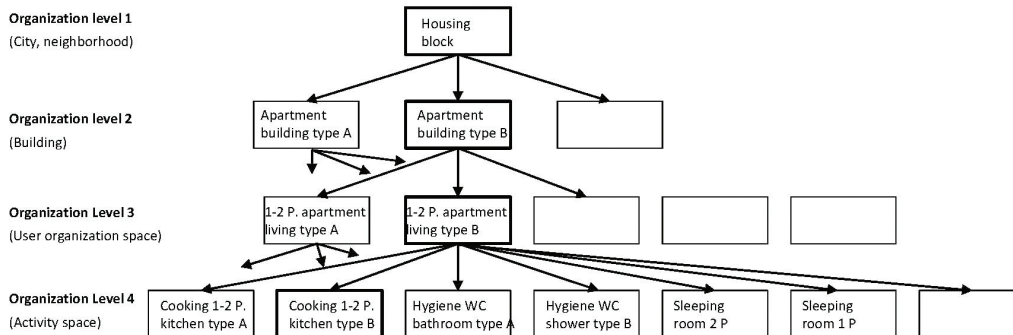


Figure 5. Hierarchical platform organization

hard in systems building. The perceived interface of architectural objects could bridge this gap through firstly encouraging concurrent engineering in the platform development and modularization phase, and secondly make the level of freedom in the platform more transparent from a user point of view in the actual design configuration phase of a project.

CONCLUSION

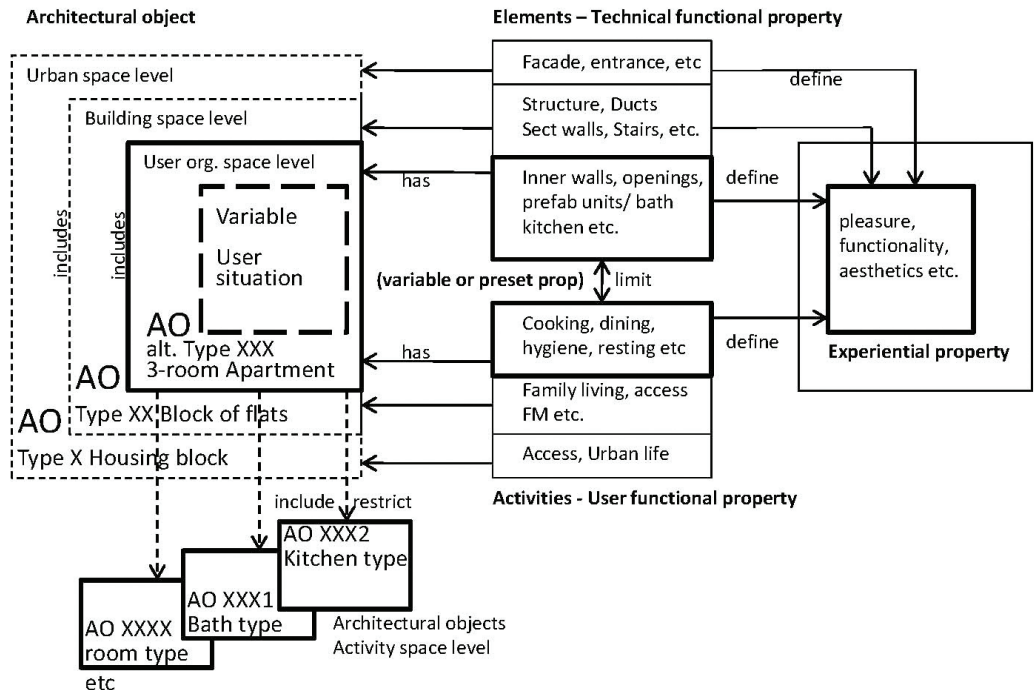
As stated a concept of architectural objects as a representation of situations have been developed together with a systems model and a process model supporting architectural design in industrialised house-building. Three case studies were presented where the idea of architectural objects in architectural design for industrialised building was tested. The results show that architects implicitly use the idea of architectural objects (situations) in the design

process, and that the idea of architectural object could be applied in industrialised house-building for configuration of assembly modules and enhance the quality of architectural design. The results however also show a need for further research concerning its implementation in a traditional BIM environment.

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Figure 6.
Example of architectural object properties and dependencies on the user organization level



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