MODELLING OF USER ORGANISATIONS, BUILDINGS AND SPACES FOR THE DESIGN PROCESS

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ABSTRACT: *The project presented in this paper aims at developing a set of theoretically well-founded conceptual schemas for buildings, spaces and user organisations. The schemas shall be used as part of a computer based prototype information system for co-ordinated design of buildings and user organisations. The schemas are presented in the formal graphical language EXPRESS-G. The first sections of the paper gives the background and objectives of the project and a short introduction to information systems. In the following sections, schemas for the conceptual framework are presented and used for development of firstly the schema for user organisations and secondly the schemas for buildings and spaces.*

KEYWORDS: *CAD, CAAD, CABD, conceptual schemas, modelling, organisation, enterprise, construction, construction works, building, spaces*

1. THE BAS•CAAD PROGRAMME

The research project presented in this paper is part of the BAS•CAAD programme which has the overall aim to contribute to the development of computer-aided design for the early stages of the construction process. BAS•CAAD is the name of a research program at the division of CAAD of the School of Architecture at Lund University. The name stands for Building and User Activity Systems Modelling for Computer Aided Architectural Design.

Until now the most wide spread use of CAD is as a drawing tool where data in the computer represent drawing elements like lines and surfaces. Currently research and development is directed towards "object-oriented" CAD where data in the computer represents the things that are designed. This development is mainly directed towards representations of buildings and other construction works. Software with these possibilities are mostly useful at the later stages of the design process when the spatial properties of the construction works are determined.

The earliest stages of the construction process, the brief and the design proposal stages, deal not only with the building but also with the user organisation as objects for design. Every construction project has a brief-formulation stage which includes a description of the user organisation and the user requirements on the building. The brief is used as a background for the subsequent stages of the process which includes spatial layout and co-ordination of the user organisation and the building.

In order to achieve a computer integrated design process it is necessary to investigate the possibilities of using CAD also for these early stages of the construction process. A CAD tool that allows a representation of the user organisation will be useful not only to the user organisation itself in the brief-stage but also to facility management.

In a recent paper Kalay, Khemlani and Choi (1996) has reminded of the complexity of modern construction and design processes, and the approaches to handle this through: development of common data exchange models, cross-education of professionals, and development of shared design environments. One of the main obstacles to concurrent design still remains in the lack of knowledge about shared design environments. Kalay, Khemlani and Choi propose two main reasons for this: 1) the fragmentation of the building industry promotes the development of task-specific building representations, and 2) the difficulties to represent semantic and syntactical information content, e.g. the fit between user needs and building, and, respectively, to represent the activities a building must support. Their suggestion to solve these problems is the development of unified building representations containing all relevant information.

With the BAS•CAAD project we attempt to contribute with solutions to the problem of shared environments by trying on the one hand to develop a unifying framework for conceptual modelling in the construction context, and on the other hand to enable an independent representation of the building user organisation. The former may facilitate exchange of information between different design tools, and thus make information more easily accessible to the participants throughout the construction and facility management processes. The latter makes it possible to design and represent activities independently of the building, and to co-ordinate the organisation and building models when relevant. If the user organisation can not have its own representation, it can only be represented implicitly, as requirements in a building model. Apart from being impractical, e.g. in the brief stage, it may also obstruct feedback of information about the impact of different building solutions on the organisation and its activities.

2. OBJECTIVES AND METHOD OF THE STUDY

The objective of this study is to develop conceptual schemas that can be used in a computer based information system for simultaneous design and co-ordination of buildings and user organisations. The conceptual schemas shall be applicable at different stages of the construction process, including the brief-formulation and operation/maintenance stages, and enable the output of different diagrams of interest to the design analysis. The schemas will support different views, for example spatial views of the building and the user organisation during spatial layout design. Other views may be needed for elaboration of organisation descriptions and space function programmes. The schemas must allow an incremental determination of properties.

In order to support the earliest stages of the design process it is necessary that the schemas can represent very generic properties and that unwanted specificity is not enforced upon the designer by the CAD-program. In this respect our approach is similar to that of Feature Based Modelling as described by Leeuwen, Wagter, and Oxman (1995). In order to achieve a conceptual consistency from generic to specific concepts, schemas are initially constructed for things and systems, then these are successively specified into schemas for organisations, buildings and spaces. The schemas developed here are compared with the kind of information traditionally required in architectural programming for a building design project.

In a forthcoming project the schemas will be implemented in a prototype computer program. The implementation will be designed to support dynamic modelling, which e.g. requires that the conceptual schemas may evolve (Eastman, Assal, and Jeng 1995). Another project in the research programme investigates the design operations characterising a computer based design tool (Fridqvist and Ekholm 1996).

3. AN INFORMATION SYSTEM

The conceptual schemas developed in this project are part of an information system which will enable a simultaneous design of buildings and user organisations. An information system is basically a data-processing system (Boman et al 1993) and an information system for design is an information system that allows design activities, for example incremental specification and classification of data in the system, and development and change of classes in the conceptual schemas.

An information system consists of a conceptual schema, an information base and an information processor (Boman et al 1993:61). The *conceptual schema* is a generic representation of the part of the real or formal world we are interested to handle information about. This part of the world is also called the *universe of discourse*, UoD. An *information base* describes the state, i.e. the values of the attributes, of the UoD at a certain time. The *information processor* is a software tool that makes it possible to query and update the conceptual schema and the information base. A *conceptual model* consists of the conceptual schema together with the information base and its data.

A conceptual schema consists of concepts and relations among concepts, developed in a formal language. Formal languages are defined by pre-established rules, which makes them suitable for building unambiguous representations, while natural languages have evolved over time for the purpose of human communication and rarely conform to simple or obvious grammatical rules (Brookshear 1989).

A conceptual schema may be represented graphically, with the main concepts in boxes and with lines representing relations between the concepts in the boxes. A conceptual schema may also be represented in a lexical language, which is a formal language that uses words and mathematical symbols to represent the items within the model (Schenck and Wilson 1994). Such languages are also called information modelling languages (Björk 1995).

A lexical language which has gained widespread acceptance in the construction information technology context is EXPRESS, which was developed in its present form to be used within STEP (Schenck and Wilson 1994). The conceptual schemas in this paper are developed in EXPRESS-G, which was developed in 1990 as a graphical counterpart to the lexical EXPRESS language (Schenck and Wilson 1994).

The schemas in the paper are presented without detailed information on data types like string, real or integer. The necessary restrictions on state spaces which are essential in the schema for the information base are not considered. The presentation concentrates on the representation of the UoD in basic entities and their relations.

Information systems are implemented in database systems. Such a system may be described as having a three level schema structure consisting of external, conceptual and internal schemas (ISO 1985). The internal schema is a translation of the conceptual schema into a data model, e.g. a relational model. External schemas provides user-customised views of the conceptual schema and information base (Boman et al. 1993).

The study at hand aims at developing conceptual schemas for buildings and user organisations as part of an information system. A separate study will use these schemas to develop the prototype information system for design of spatial layout plans of buildings and organisations.

4. CONCEPTUAL SCHEMAS FOR SYSTEMS

To develop a conceptual schema as part of an information model means to make a formalised description of the UoD. A formalised scientific background for the conceptual schemas simplifies the translation into computer implementable languages like EXPRESS. In this study the description of the UoD is based on a scientific ontology formalised to some extent with elementary mathematical concepts such as those of set, function and Boolean algebra (Bunge 1977 and 1979). A short presentation of some basic concepts in Bunge’s ontology, among others those of thing, property and system is done by Ekholm (1996).

In the EXPRESS-G schemas below the circle at the end of a line shows the direction of a relation. A broader line indicates a subtype relation. An * marks a restriction on a relation.

4.1 From things to sociotechnical systems

A *thing* is a concrete object, its basic properties are environment and structure. The environment is the set of things with which the thing interacts. The structure is the set of its relations to the environment (Bunge 1977). The relations are bonding and non-bonding; bonding relations affect the state of the related things, while non-bonding relations do not. For example relations to reference frames are non-bonding, like spatial and temporal relations. See Fig. 1. A thing with composition and internal structure may be represented as a system.

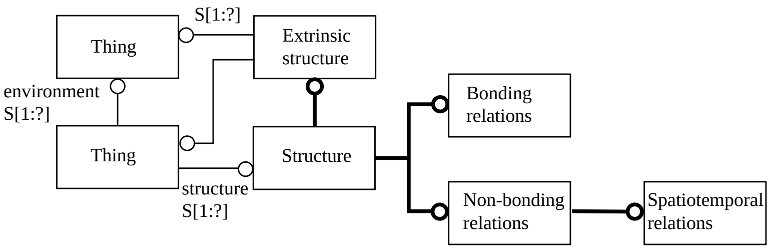

FIG. 1: Thing

A *system* is a complex thing with bonding relations among its parts, it has composition, environment and structure, both intrinsic and extrinsic (Bunge 1979:8). A relation belonging to the intrinsic structure relates at least two parts of a system. See Fig. 2.

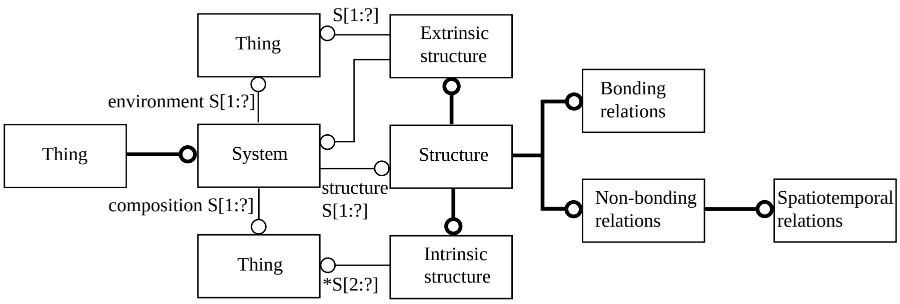

FIG. 2: System

The properties of human individuals are basic to the properties of human social systems. A human individual is characterised both by motor behaviour and mentation (Bunge 1979:174). An human individual is capable of thinking and of interpreting things in its environment. Interpretation results in mental constructs, e.g. thoughts, feelings and ideas. Humans interpret things in two main ways, epistemically and semiotically. An epistemic view of a thing is to analyse its composition, environment and structure. A semiotic view means to interpret a thing as a sign in a communication system (Bunge 1974:1). See Fig. 3.

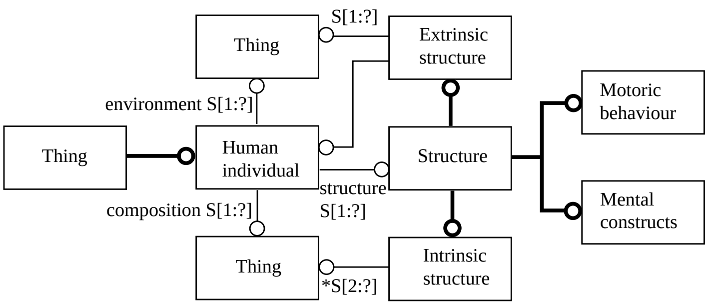

FIG. 3: A human individual as a system

A human *sociosystem* has a composition of human individuals, its structure is the social behaviour repertoire, i.e. interaction among human individuals. Social relations depend on communication, i.e. the exchange of information (Bunge 1979:180). See Fig. 4.

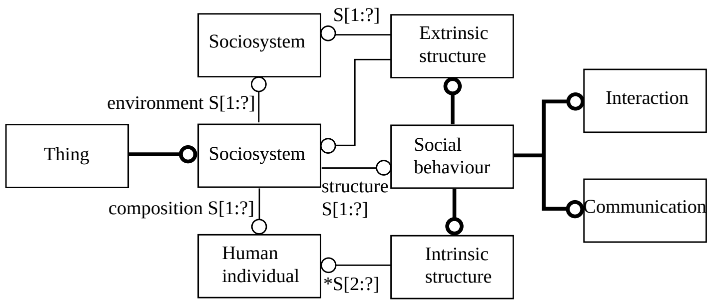

FIG. 4: Sociosystem

Human social behaviour can be creative and goal-directed. A *goal* is a foreseen state of a thing. An *activity* is a sequence of goal-directed actions with intention to transform the state of a thing. In order to perform an activity, the system, man or machine, must be a control-system. An *artefact* is a man-made or man-controlled system; it is made with a purpose to make certain activities possible. An activity that involves the use of artefacts is a property of the composite ”socio-tool” system. For example machines make new activities possible like drilling for oilwells and making computer tomographic images. Such a man-machine system is called a *sociotechnical* system (Emery and Trist 1960).

The relations between the sociotechnical system and that part of the environment which is transformed during the activity are called *transformation-relations*, and the corresponding activity can be called *transformation activity* (Bunge 1979:189). The relations between man and tool during an activity can be called *tool-relations* (Ekholm 1987). See Fig. 5.

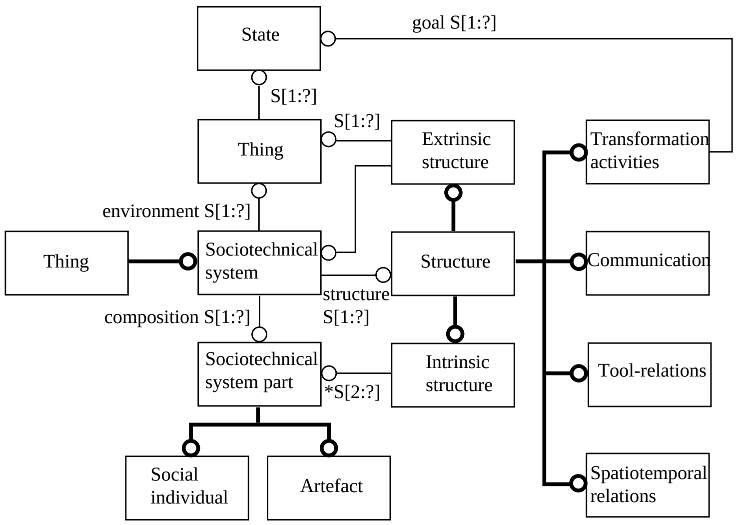

FIG. 5: Sociotechnical system

5. A CONCEPTUAL SCHEMA FOR ORGANISATIONS

5.1 Characteristics of work organisations

Work is a specific kind of activity, it is a useful activity (Bunge 1979:197). A sociosystem engaged in some work activity is in management science called an ”organisation” (Child 1984), ”human activity system” (Checkland 1981), or ”enterprise” (Bubenko 1993). Work can be of different kinds, the basic categories are economic, cultural and political (Bunge 1979:196). Economic work aims at transforming the environment into a foreseen state or goal. Cultural work aims at communicating thoughts, feelings and ideas. Political work aims at controlling economic and cultural work.

Human society is a self-supporting system composed of four different subsystems, the kinship system and the economic, cultural and political systems (Bunge 1979:189). The organisations of modern society are complex sociotechnical systems organised in functional units composed of human individuals, tools, machinery, and equipment. The functional units, or subsystems, contribute with their activities to the functions of the organisation as a whole. Since an organisation is characterised by work it has at least an economic or a cultural subsystem, together with a political subsystem, the management.

One of the main objectives of the management of an organisation is to define the goals of the organisation. Each functional unit within the organisation is characterised by its goal. Understanding and expressing the goals of an organisation is a basic starting point for organisational analysis and design (Checkland 1981). The goals of different organisational units can be related and represented in a separate goal-schema or objectives-model as part of an enterprise model (Bubenko 1993).

The structure of an organisation is its social behaviour including its work activities. A human individual's behaviour during an activity is called a *role* and includes both mental and physical activities. A *job* is the basic functional unit in a work organisation, it is performed by a human individual or a machine. A single job is often not sufficient to encompass all the activities that are required to carry out a complete task. In organisational design the focus is on the work group and its task, not on individual jobs. A *task* is ”the transformation of inputs into output objects such as fabrications, assemblies, projects or complete services” (Child 1984:24).

A level order of an enterprise has at its lowest level the single job. Single jobs are combined into work groups, sections or teams. Work groups are composed into *departments*, which in their turn compose into *functions* or *divisions*, the highest compositional level below the organisation or enterprise as a whole (Child 1984:85). Systems in all these subordinate levels are parts of the organisation as a whole. See Fig. 6.

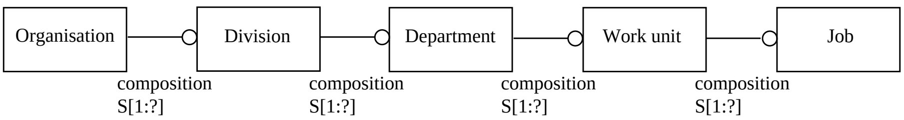

FIG. 6: Example of a level structure of organisation units

The amount of levels in an organisation depends on factors like span of control of managerial and supervisory staff. The amount of levels together with the span of control is referred to as the *shape* of the organisation. The shape of the organisation also depends on the main production technology (Child 1984:69).

A kinship system like a family household is not a work organisation but it has tasks like rearing of the young and caring for the elderly, or tasks like cooking, dishwashing, laundry, and cleaning. Tasks may be performed as individual jobs or by a work group consisting of some or all household members together. The level order of a household has at the lowest level the individual jobs, which compose into household task groups, which finally compose into the household as a whole.

5.2 The organisation as a system

As a conclusion of the considerations above, an *organisation* may be defined as a system with:

1. A *composition* of social individuals and machines, tools or other equipment, organised into organisation units. The composition has a level structure with a lowest level of job units e.g. individuals or machines; these combine into higher levels like work groups, departments and divisions. Among the subsystems are an economic or cultural system, and a control system that manages the former.

2. An *environment* of things with which it interacts and which is partly transformed by the organisation's work. To the environment belong for example the material resources transformed by work and the resulting products. Also sociosystems towards which the organisation directs its cultural work belong to the environment. Finally the organisation has a physical site, for example a building or the natural environment.
3. A *structure* including an intrinsic social network based on work, with tool-relations to the artefacts in the system. Some members of the organisation manage others with respect to their work in the organisation. To the extrinsic structure belong the economic and cultural work as well as relations to the site. To the structure of an organisation belong its spatiotemporal properties.

See Figure 7.

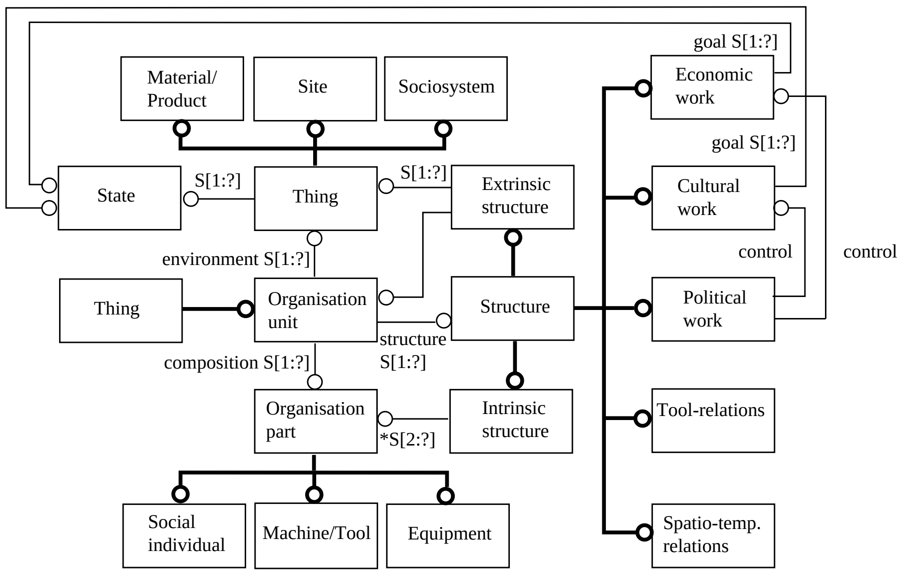

FIG. 7: A conceptual schema for an organisation

5.3 Requirements on an organisation schema for the building design process

An organisation schema that shall be used for information structuring in the early stages of the building design process must fulfil certain requirements. The basic compositional and structural entities of the schema in Fig. 7 can be compared with the information entities needed in spatial layout planning as described by Hales (1984:17). The necessary data are:

1. *Personnel data*: numbers, skills, attitudes, working hours, , physical needs etc.
2. *Product and material data*: quantities, activity cycles, size, weight, composition, etc.
3. *Routings or manufacturing sequence data*: data for products and material in a production process; procedures for the work process in administrative or institutional facilities.
4. *Furniture, machinery and equipment data*: quantities, activity cycles, size, weight, required installations etc.
5. *Building (and process) support*: mechanical and electrical systems, HVAC-systems, plumbing, lighting, maintenance, waste disposal, pollution control, fire control, etc.
6. *Personnel support*: food services, break and recreational facilities, parking, first aid, etc.
7. *Activity areas*: ”Activity areas” are organisational units based on functional or product/process based grouping of activities. All project data on flow, communications, space, equipment, personnel, etc. are collected and reported by ”activity area”.
8. *Material flow*: Data on material flow between activity areas; by estimates; by work sampling or other formal survey; by extraction from production control reports; etc.

9. *Communications*: Data on personnel communication based on surveys which display both the overall communication pattern and the aggregate relationships between workers.
10. *Activity relationships*: Communications and flow are the chief bases of relationships between people and departments; other issues are shared supervision, shared equipment, shared records, shared utilities, etc.

Of these categories all except building support are organisational data. In the schemas developed in this study, building support belongs to the schemas for buildings and spaces. Activity areas in Hales' terminology are organisational units in different levels. The fact that they have spatiotemporal characteristics is probably the reason for the name used by Hales.

5.4 The spatial structure of an organisation

The spatiotemporal properties of organisation units depend on the kind of organisational grouping employed. There are three main principles for organisational grouping: the functional, product, and matrix principles. A *functional grouping* collects persons with similar expertise and those who use the same kind of resources. A *product grouping* combines people with different expertise to contribute to the same product or family of products. A *matrix grouping* has a basic functional structure where task groups are formed for limited periods of time (Child 1984:87).

An organisation has a spatial extension traditionally called activity space. The activity spaces are of different scale from the smallest, defined by the human body and the used tools, to the space determined by the organisation as a whole. In human activities, e.g. an individual's job, the body and reach characteristics belong to the key determining factors. The spatial extension of a work unit, composed of individuals with their tools and equipment, also depends on the material used in the process and the resulting products. Persons, equipment and material may change position and dimension over time which makes the activity space time-dependent.

Task groups are often spatially distinct units, and in spatial planning such units are called activity-areas (Hales 1984). Unfortunately the term overemphasises the spatial properties of the unit at the cost of its functions. In organisational design the spatial allocation of activities is of major importance. The spatial lay-out of activities should be based on criteria like effective information processing, economy of staffing and resource use, and control (Child 1983:104). Child also suggests a method for deciding on the spatial allocation of activities. The suggested method is similar to that presented as Muther's Systematic Layout Planning Method (Muther 1973).

The spatial allocation process starts with a systematic plotting of the various workflows in the organisation. The constituent tasks and the staff involved are identified and the activity areas for tasks including staff are determined. The next stage consists of evaluating the links between the tasks, and considerations are made about the closeness of the activity areas. The appropriate links between the activity areas can be analysed in a so called relation matrix. The method is called cluster analysis and may be a useful tool in the spatial allocation analysis. The tool itself does not solve conflicting interests in the organisation, but it can be helpful in presenting the considerations made to those affected by the decisions (Child 1984:108).

Methods for analysis of the spatial distribution of an organisation are also presented by Hales (1984) and Kumlin (1995). The analysis can be supported by graphical representations, examples of such tools are: adjacency matrices, affinity diagrams, flow-charts, blocking and stacking diagrams, graphic and net area displays, spatio-temporal diagrams etc. These tools are computer implementable and should be part of computer aided organisational design programs.

5.5 Other work on organisational modelling

International work on standardisation of enterprise models for communicating and transferring organisational data is going on within ISO TC185 SC5 WG1 (ISO 1995). The approach in this work is based on systems theory, however the material is still under development and cannot be used as a background for this study.

Principles for developing conceptual schemas for organisational design and change are described by Checkland (1981) and Bubenko (1993). Basic concepts of these methods should be possible to accommodate in the organisation schema developed in this study.

According to Checkland a ”human activity system” can be described by a ”root-definition”, which is a description of what the system is, i.e. its ultimate goal. Such a system has: a *transformation process* i.e. a transformation of input into output; an *owner* outside of the system which determines whether it may exist or not, for example the management of the organisation; *actors* i.e. persons acting within the system and doing the transformations; *customers*, i.e. persons outside the system that are affected by or that affect the system; *environmental constraints,* i.e. factors belonging to the environment of the system which cannot be changed by the system; a *weltanschauung* which makes up a meaningful conceptual context to the system. Of all the concepts in Checkland’s definition it is only the ”weltanschauung” which can not be represented by an entity in the proposed schema. On the other hand a ”weltanschauung” should not be part of a schema but be implicit in the goals of the organisation and part of its *raison d’être*.

An Enterprise Model according to Bubenko is organised as a system of models. It supports the requirements engineering process in information systems development with well organised knowledge models. A complete Enterprise Model includes the following submodels:

1. The objectives model (OM) represents the goals and problems of the enterprise.
2. The activities and usage model (AUM) describes the processes, tasks, and activities of the enterprise, and the information and material flows between them. External agents outside the scope of the organisational activity are identified. The activities are motivated by the components of the objectives model, and performed by the components of the actors model.
3. The actors model (AM) represents the actors in the studied activities (individuals, groups, job-roles/positions, organisational units, machines, etc.) and their relationships, such as part of, kind of, and reporting to. The model has links to other models like objectives or activities.
4. The concept model (CM) is used to define the set of object types, relationships, and object properties of the application, i.e. the ”ontology” of the ”Universe of Discourse”.
5. These four models are integrated into the information systems requirements model (ISRM).

See Figure 8.

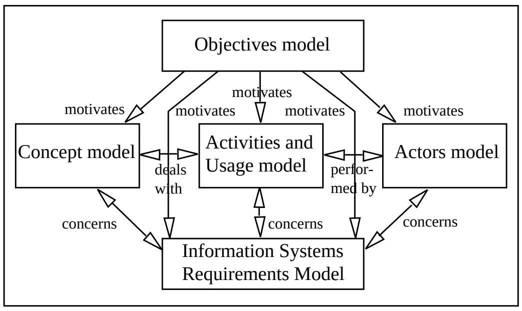

FIG. 8: An Enterprise Model schema according to Bubenko (1993)

The entities above have corresponding entities in the organisation schema proposed in this study. The Enterprise Model is delimited in that it does not relate activities to spaces. Further development is among others concerned with incorporation of time and space aspects (Kirikowa and Bubenko 1994).

Other research on enterprise modelling for example for the offshore industry is done in the CAESAR project described by Christiansen and Thomsen (1994).

Explicit representation of organisation units for CAD has to the present authors' knowledge only been done by Eastman and Siabiris (1995). The authors identify ”activity units” composed of furniture, equipment and activity area. The emphasis is on spatial properties, and the concept ”activity area” has similarities to the concept mentioned above in (Hales 1984). Other approaches identify ”functional units” (Flemming and Chien 1995) or ”space units” (Carrara, Kalay and Novembri 1994). These represent functional requirements and generic spatial properties of the buildings spaces, and in that way only indirectly represent the organisation units.

6. CONCEPTUAL SCHEMAS FOR BUILDINGS AND SPACES

6.1 A framework for building information

The concrete functionally distinguishable things that are produced in the construction process, namely the construction artefacts, are *infrastructure units*, *construction works*, *construction work elements*, *element parts*, and *spaces* (Ekholm 1996). Construction artefacts are composed of assembled and transformed *construction products* (ISO 1994).

Construction works are specifically designed to be used in activities that require for example a loadbearing ground structure, servicing installations, or æsthetic and symbolic expression. Examples of construction works are buildings, streets, canals, bridges and parks. Buildings are a specific kind of construction works, they are built to accommodate user organisations, and have an enclosed space for control of climate or protection against intruders. Construction works are aggregated into larger so called infrastructure units, characterised by a common location and by being used by a social organisation for a purpose, e.g. the construction works of a university campus or an airport.

The functionally defined parts of construction works are elements and element parts. An element like a gypsum wall with a space enclosing function may in its turn be composed of element parts like a door, scantlings and gypsum boards. The element parts constitute the lowest level of construction artefacts, they do not have the complete function required to be classified as element (Ekholm 1996).

Infrastructure units, construction works and their parts make up a level order of increasing complexity with the levels:

- infrastructure unit (town, village, university campus etc.)
- construction works (streets, houses, canals, bridges etc.),
- construction work elements (column, wall, duct etc.)
- element parts (wooden studs, gypsum sheets, etc.).

A building has a site. The concept "site" refers to the immediate natural surroundings of a building for example a place on the ground, the climate factors (wind, rain etc.) and also other things that may have bonding relations to the building. The site-concept is central in the COMBINE model (Nederveen 1996).

The internal bonding relations between the parts of a building can be caused by gravitation or by fixing devices. Among the external relations are the functions to the users and the transfor-mation-relations to the site, both of which are bonding relations. Among the non-bonding relations are the spatial relations, and indirectly, the interpretation-relations to those who experience the building as a system and a sign, in order to appreciate its architecture and history. These concepts are related in a conceptual schema for construction works in Fig. 9.

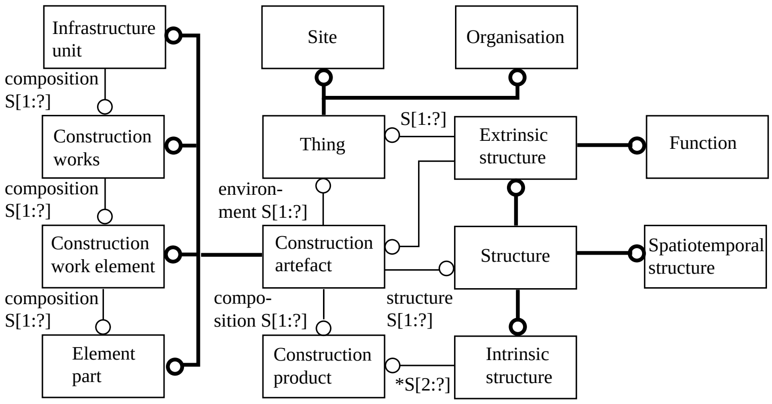

FIG. 9: A conceptual schema for construction works

6.2 Spaces

A spatially and functionally delimited region of a building or a building element is traditionally called a *zone* or an *area*, e.g. fire zone, parking zone, tiled area or painted area. An enclosed area within or outside of a building is called room or space. Spaces and construction works are alternative views on the same collection of things. The view of the construction work as space is convenient when a limited region is of interest, e.g. a room where only spatial and functional views are relevant and the compositional view is not. Within the spatial view the same thing is allowed to be part of different spaces, for example a wall in a building may be part of two adjacent rooms. Therefore it is not correct to say that a building is composed of rooms, that larger spaces are composed of smaller spaces, or that a building has a system of spaces, expressions that are frequent in the construction context. Activity areas with the meaning organisation units are often referred to as ”spaces”. In that case it is correct to say that ”larger ‘spaces’ are composed of smaller ‘spaces’”. However, in order to avoid misunderstandings this terminology should be avoided.

The spaces of a building are characterised both by spatial properties like area and volume, and by enclosing properties e.g. enclosing to light, sound, air or fire. Enclosing is not necessarily a material property but may also be dependent on a person’s interpretation. An office space may have floor, ceiling and furniture, e.g. a bookshelf or a screen, but no walls; still it is experienced as an enclosed space. A space function program developed in architectural programming contains requirements on the buildings spaces, e.g. surface materials, fire resistance and sound reduction levels. The properties of rooms in buildings are designed for occupancy of users, machinery and equipment. Spaces are classified by their basic function in relation to the users and other agents for example office and communication spaces and climate- and fire-zones (ISO 1994).

In order to develop a conceptual schema for spaces, an explicit definition of the space concept is necessary. Spatial relations are non-bonding relations among things, and a *space* is a collection of spatially related things (Bunge 1977). According to this definition any collection of things may be regarded as a space; both a constellation of stars, an alley of trees and a building of building elements are spaces. Such a collection of things is not defined by bonding relations among its parts or its functions as a whole, still it has emergent properties, e.g. spatial characteristics like shape. The parts of a space may constitute a system, for example the constituents of the egg shell, the fabric and poles of a tent and the elements of a building are parts of systems.

In the construction context spaces are constituted by construction works and their parts. Of specific interest to the users are spaces that can be used for occupancy and that have enclosing functions. This leads to the following definition of space in the construction context: ”*A space in the construction context is an aggregate of construction works, their parts or other things with materially or experientially enclosing properties*”, see also (Ekholm 1996). See Fig. 10.

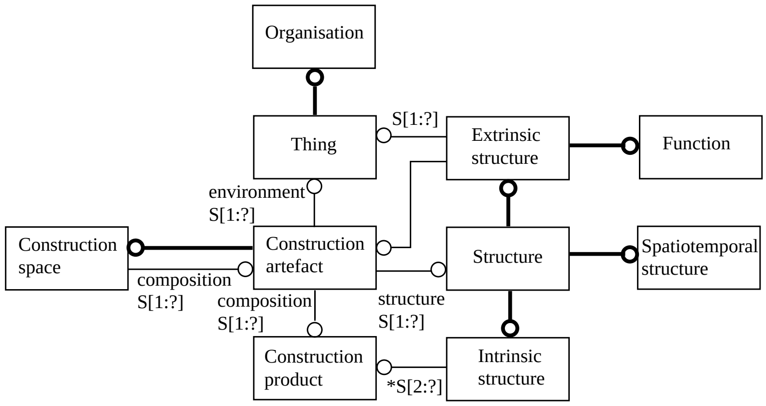

Figure 10: A conceptual schema for construction spaces

The user organisation that uses the buildings’ spaces belongs to the environment of the spaces. The question of which parts belong to the spaces and which belong to the organisation depends on the context. For example in one case a bookshelf is considered a building element and belongs to a space, while in another case the bookshelf is considered part of the organisation. Spatial layout design deals with the spatial co-ordination of spaces and the user organisation located within the spaces.

The definition of space suggested here is not in accordance with everyday language where space refers to a void enclosed by e.g. building elements. But, as shown above, construction praxis treats space as a collection of elements with certain spatial and enclosing properties. This concept of space as a factual material thing is practical in construction, but contrasts to our visual perception of space as something enclosed by surfaces of things. For everyday purpose we think about the visually perceived space and act on the basis of the factual material space. In the approach to conceptual modelling chosen for this project it is necessary to stay with the factual concept of space in order to achieve a consistent framework.

In today’s Building Product Data Models the space concept most often refers to the void enclosed or bounded by a ”structure” or ”entity”. Such a concept of space is used by Björk (1992), Eastman and Siabiris (1995), in the Building Construction Core Model of STEP (ISO 1996), as well as in the COMBINE model (Nederveen 1996). An exception is presented by Watanabe (1994).

According to the definition presented earlier, a space is composed of physical parts, e.g. enclosing elements. Its shape, the ”void”, is an emergent property of the space, having geometrical attributes like ”volume” or ”area”. This space concept can be assigned functions which the ”void” concept can not. In practise this problem is overcome by interpreting ”bounded by” as ”composed of”, and the models work. See Fig. 11 for a comparison of the basic modelling principles.

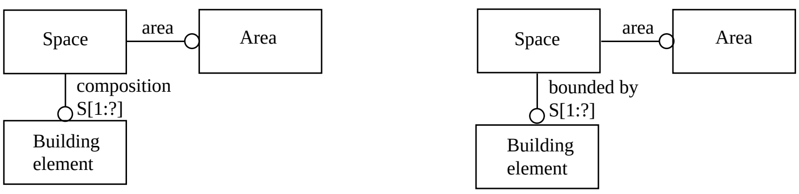

FIG. 11: Schemas for two different space concepts

7. CONCLUSIONS

The study has developed a set of conceptual schemas of increasing specificity from generic for things and systems, to specific for organisations, construction works and spaces. The schemas have been developed with the use of a consistent theoretical framework, a scientific ontology, and related to existing knowledge in the field of organisational, building, and space modelling. However, within the limited space of this paper, and the time available for the study, it has not been possible to make a exhaustive investigation of other work. This remains to be done both concerning organisational modelling and the modelling of spaces. It also remains to test the schemas empirically. The generic schemas for systems and sociotechnical systems can only be tested vicariously, through the more specific schemas. These will be tested through implementation in a prototype computer program for spatial co-ordination of user organisations and buildings.

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