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Ekholm, Anders

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Title: # Principles for classification of properties of construction objects

Author(s): Anders Ekholm
Institution(s): Dept of Construction and Architecture, LTH, Lund University
E-mail(s): Anders.Ekholm@caad.lth.se

Abstract: *This report presents a proposal for a classification of generic properties of systems and an application to construction objects. The background is a documented need for classification expressed in international construction co-operation within ISO, IFC and other standardisation efforts, to be used in different applications like classification systems and product libraries. The general property classification presented in this paper has been developed on the basis of general property theory and systems theory. It is related to a selection of earlier work in property systematic in the construction sector. The report concludes that property classification is important, but that continued work on standards for presentation of properties for construction objects must be done.*

Keywords: *Properties, attributes, classification, systems theory, construction*

The need for classification of properties

The aim of the work presented here has been to develop a theoretical foundation for classification of properties of construction objects, i.e. construction entities like buildings and civil engineering works, parts of construction entities and construction products. The objective has been to clarify the principles for classification, not to develop attribute tables or lists for different construction objects.

In every context where specification of a construction object is pertinent, e.g. in specifications for construction works, environmental declarations, product catalogues and product libraries, the need for structuring attributes occurs. The ISO Technical Report 14177 which was compiled to prepare for the international construction classification standard ISO 12006-2 (ISO 2001), states that a classification of properties is a necessary step towards a sound development of information systems (ISO 1994).

In different ongoing projects within the national Swedish RTD-programme "IT in Construction and Real Estate Management 2002" (IT Bygg & Fastighet) this need has also been observed (Svensson et al 2000), and (Häggström et al 2001). The need for classification of properties is perhaps most evident in applications for Internet based search for construction products, where attributes are a key search variable (Engdahl 2001). In the seminar series ”Nordic Product Libraries” organised by the Nordic IAI, the need for a common classification to be used in IFC attribute libraries and PropertySets has been discussed. Research into CAD-systems for the early stages of design suggest that such systems should be property-oriented, rather than class-oriented (Garret and Hakim 1994, Ekholm and Fridqvist 1998, and Fridqvist, Hendricx and Leuwen 2001). These examples all require a systematic for properties.

The theoretical background for this work is mainly based on Mario Bunge's works, primarily his ”Treatise on Basic Philosophy” (Bunge 1974, 1977, 1979 and 1983a and 1983b). Bunge's work belongs to the ”realist” tradition within the philosophy of science and technology, which is compatible with the, often tacit, praxis of modern science. It is chosen as a framework since it represents a model work of both consistent synthesis and consideration of diverging positions within its wide field.

The next section presents the theoretical framework and a proposal for classification of properties of concrete systems. Then, a selection of earlier works on property systematic in the construction sector is analysed. Based on this, an example of a classification of properties of construction entities is developed. Finally conclusions and remaining questions are discussed. The research was financed by IT Bygg&Fastighet 2002, and Formas.

Properties of objects

Concrete and conceptual objects

Objects are generally defined as entities, concrete or conceptual, towards which feelings, thoughts or actions are directed. Objects are characterised by their properties, but the distinction between an object and

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its properties is a purely conceptual operation, there are no objects without properties or vice versa (Bunge 1977:26). Conceptual objects, e.g. feelings or thoughts, are *mental constructs* with abstract or conceptual properties (ibid:58), while non-conceptual or concrete objects, are *things* with concrete properties (ibid:110).

Primary and secondary properties

Scientists and philosophers like Galilei, Newton, Descartes and Locke distinguished between primary and secondary properties. Primary properties, e.g. velocity or mass, exist independently of an experiencing subject, while secondary properties emerge in the relation between a thing and a subject. Secondary properties are perceived through our senses, e.g. colour, intensity of sound, and shape or gestalt. Primary properties of things are here called *material*, while secondary properties are called *cultural*. See Figure 1.

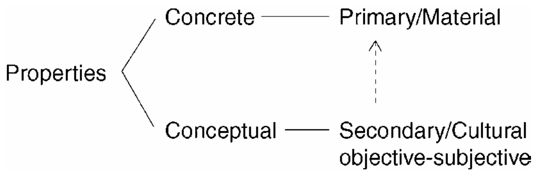

Figure 1. Basic property types

In a somewhat widened sense, secondary properties can be understood as man's conceptions of things, (ibid:67). These include not only properties as they are perceived through our senses but also those, which are produced through reason, e.g. scientific theories.

Propositions that aim at describing a thing's material properties, by certain standards independently of an observer, are called *objective* (Bunge 1983a:155). They can be true or false depending on their correspondence with the material properties. With increased knowledge, previously true propositions can be considered false or in need of improvement. Propositions that aim at describing a thing's cultural properties are *subjective* if they depend on an individual and *inter-subjective* if they are based on conventions in a social system. Subjective propositions are neither true nor false.

Properties of systems

The properties of a system can be divided into intrinsic and mutual (ibid:65). Examples of a system's *intrinsic properties* are its composition of parts and their resultant properties like mass and material, and properties that emerge in relations between the parts, e.g. density, state of aggregation, surface structure, etc., as well as intrinsic events like shrinkage, expansion, radiation, emission and decomposition. Intrinsic properties are possessed by the object alone while *mutual properties* emerge through relations between the system and its environment. The system's intrinsic properties are *basic* to its mutual properties.

Bunge distinguishes between three kinds of mutual properties, which emerge in the relation between:

- object and environment
- object and reference frame
- object and subject.

Figure 2 illustrates the main categories of property presented here.

Properties in the relation object-environment

A *function* is a mutual property based on bonding relations between a thing and its environment. Functions affect the state of the related things. Intrinsic properties are basic to functions, e.g. porosity and impenetrability to gases of a thing are prerequisites for its heat insulating function.

Properties in the relation object-reference frame

A *comparative* property is based on a non-bonding relation between a thing and a reference frame. A reference frame is a thing that serves as a comparison concerning some property. Spatial and temporal properties, velocity, degree of temperature, hardness are examples of comparative properties.

A spatial relation is defined as a non-bonding separation relation between things. Properties like length, width, and height are properties relative to a spatial reference frame. Time is defined in analogue with space as a separation relation, but between events. A reference frame for time, e.g. a clock is characterized by its regular process.

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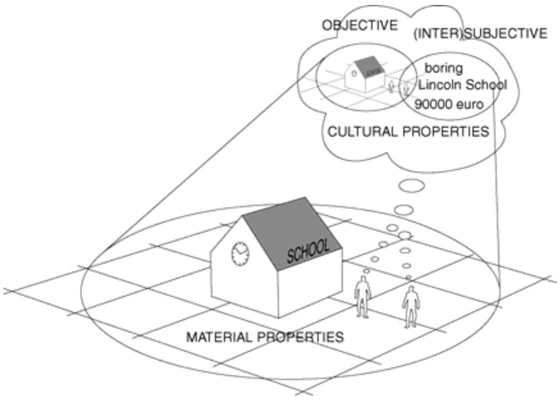

Figure 2. Main categories of properties

Properties in the relation object-subject

The mutual properties that emerge in the relation between object and subject are perceptions and interpretations of the object; they are *cultural properties*. Perceptions, or *phenomenal properties*, are active "reproductions" of events in the environment and the individual's body but also depend on earlier experience and ideas (Bunge 1979:154 and 1983a:35). Phenomenal properties are both subjective and objective, they are experiences of a subject but may correspond to an object's material properties. Examples of objective phenomenal properties are loudness, colour, and warmth, while comfort, beauty, and excitement, are subjective phenomenal properties. Phenomenal properties can be grouped according to the object's visual shape, colour, light, texture, tactile, and auditory properties (Hesselgren 1954).

Experience of a thing does not make halt at perception, but also depends on conception or thought. A specific thought activity is *interpretation*. Bunge distinguishes between two different kinds of interpretation, epistemic and semiotic (Bunge 1974:1). *Epistemic* interpretation means that the subject through experience of the object tries to know its material properties. Therefore, epistemic properties may be objective. Epistemic interpretation is used both in everyday life and in science. The object may be described as a system, with environment, parts and relations. *Semiotic* interpretation means that the subject tries to know the meaning that the object conveys, seen as a sign in a communication system. Signs are interpreted as meaningful objects rather than as concrete systems. Signs may be linguistic e.g. newspapers and books, or non-linguistic, e.g. light signals and road signs. Semiotic properties are inter-subjective and based on conventions in a social system.

To sum up, the properties in the object-subject relation are

- phenomenal properties, i.e. perceptions related to an object,
- epistemic properties, i.e. objective conceptions of the object's properties, and
- semiotic properties, i.e. meanings of objects.

Qualitative and quantitative properties

Properties may be qualitative or quantitative (Bunge 1977:68). A quantitative property, e.g. distance, comes in degrees while a qualitative property, e.g. load-bearing, either exists or not exists. Quantitative properties may be represented by attributes with some value domain.

Determination of properties

During design, the properties of a possible artefact are determined. Phenomenal properties like comfort and security can serve as a starting point for determination of functions like climate control and burglary protection. Basic to these are functions like heat resistance and locking system. Both can be represented by quantitative attributes, e.g. "u-value", and "break up resistance time". In their turn, these properties are based on properties of the constituent material, and durability and fastening of construction products.

Classification

The process of discriminating between objects results in the formation of kinds, e.g. the class of buildings or the class of ideas (Bunge 1979:165). A class concept generally *refers* to an object as a whole (Bunge

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1974:15), while a class concept that specifically *represents* a property of the object is an *attribute* (Bunge 1977:59). An example is the attribute "*v"* which refers to a moving object and represents its velocity.

To classify is to group a collection of objects into mutually disjoint subsets for a specific purpose. The sets are ranked in a level order where sets with a higher rank *include* sets with a lower rank (Bunge 1983b:325). To classify properties of objects is in principle the same as to classify the objects having these properties, since the object-property dichotomy is a purely conceptual operation. A classification of concrete properties may result in a table of attributes, each representing a property.

Classification of properties of concrete systems

Material properties

Material properties of concrete systems are independent of human experience, but may be truly represented by objective conceptual knowledge. The class dividing properties in the first rank are based on the distinction between mutual properties of the system and its environment, and intrinsic properties of the system. Mutual properties are divided into those based on bonding or non-bonding relations.

1 Functional (mutual properties based on bonding relations to the environment).

To this class belongs functions in relation to the environment, including side-effects and environmental effects. A function may be time dependent.

2 Comparative (mutual properties based on non-bonding relations to the environment)

Comparative properties are based on non-bonding relations to reference frames, e.g. position, geometry, and temporal properties like birth date, deletion time, order, rhythm, and pace.

3 Compositional (intrinsic properties based on parts and relations among parts)

Compositional properties are intrinsic to the system, e.g. material, mass, density, surface structure and intrinsic processes. The parts of the system and the larger whole which it is part of, also characterise the system but these are things, and not properties of things like function and mass.

Cultural properties

Cultural properties of a system are experiences and thoughts of a subject related to the system but not intended to represent the system's material properties. The properties of an individual are *subjective*. If they are shared by others through convention, they are *intersubjective*.

The class dividing properties in the first rank are based on the distinction between individual perceptions and social conventions, i.e. *phenomenal* and *semiotic* properties respectively. Semiotic properties may be divided into *symbolical* and *administrative*. The former allows the system to be interpreted as a meaningful sign or a symbol for another thing, while the latter are assigned to the system for administrative reasons, e.g. for identification, naming, description or assessment. *Price,* the exchange value of a system, is an administrative property.

4 Phenomenal (mutual properties determined by the individual's experience)

Phenomenal properties are based on the individual's experience of the system. They can be divided into objective and subjective. Examples of the former are colour, loudness and brightness, and of the latter are comfort, beauty and safety.

5 Symbolising (mutual properties based on interpretation of the system as a sign or symbol)

Symbolising properties are based on semiotic interpretation of a system as a text or symbol, they are information in a communication system. The symbolising properties can be divided into linguistic or non-linguistic, books and road signs respectively have symbolising properties.

6 Administrative (mutual properties assigned to the system in an administrative context)

Administrative properties are assigned to the system so that it can be identified and categorized in a social system. Examples are ID, name, classification, and price but also descriptions and property declarations.

Existing systematic for properties of built objects

Check lists for technical documents

The investigation "Kontrollistor för tekniska dokument" (Check Lists for Technical Documents) is a compilation of attributes for construction entities, construction entity parts, and construction products. It is a checklist to be used in investigations of properties of construction objects. It is based on earlier Swedish and international work, e.g. the CIB Master List 1972 (Fors and Karlsson 1977).

Properties are divided in two main categories. The properties in the category ”Functional prerequisites” are mainly functions intended to be used as a basis for requirements on construction objects, e.g. in specifications. The properties in the category ”Properties of material and constructions” are also to a large extent functions. They represent the construction entity's ”capacity to meet requirements and expectations by society and individuals”.

The difference between these types of functions is not described explicitly but ”Functional prerequisites” are qualitative attributes and can be stated independently of a technical solution, e.g. ”durable”, and ”internal climate”. In contrast, functions in the category ”Properties of material and constructions” are more specific and depend on the technical solution. They are represented by quantitative attributes.

CIB Master List 1993

The CIB Master List is the globally most well known, wide spread, and applied list of properties (CIB 1993). The CIB Master List should not be regarded as a classification, since the classes are not disjoint, but as a recommendation for disposition of information in technical documentation of construction objects in the context of design, production, distribution, use, and maintenance.

The main headings in CIB Master List are:

0 *Document*
1 *Identification/Brief description*
2 *Requirements*
3 *Technical description*
4 *Performance*
5 *Design work*
6 *Site work*
7 *Operation*
8 *Maintenance, repair, replacement, disposal*
9 *Supply*
10 *Manufacturer/Supplier*
11 *References*

The headings are adapted to present information for different needs. Under ”Document” is collected information about the documentation, so called ”meta data”. Under ”Identification/Brief description” is the product's name and a short summary of functions and technical solution. Similar to the ”Check Lists” above, the Master List distinguishes between ”Requirements” and ”Performance”. Under ”Requirements” are listed functional requirements, exemplified by those of the European Construction Products Directive (Council Directive 89/106/CE 1988). ”Performance” are functions represented by quantitative attributes. Under the heading ”Technical description” are presented compositional properties like material.

The rest of the headings describe other properties that are regarded relevant to the description of a product, e.g. in the context of delivery, assembly, use, and maintenance. The content under these headings is of a descriptive and advisory character, e.g. how the product should be handled and protected, and recommendations for dimensioning regarding different functional requirements.

To conclude, the CIB Master List is not a classification but a recommendation for presentation of properties from different aspects. The principles of the CIB Master List can be recognised in the disposition of e.g. the Swedish Building Catalogue, which presents information about construction products (Svensk Byggtjänst 1998).

ISO/TR 14177

The ISO/TR 14177 was developed as a background for the work with the international standard for construction classification ISO 12006-2 (ISO 1994). As mentioned in the introduction to this article, the Technical Report states that a classification of attributes is a necessary step towards a sound development of information systems. The following main categories of properties are suggested:

- *Performance*
- *Function*
- *Shape*
- *Location*
- *Material*
- *Price*
- *Production time*

”Performance” is defined as ”the behaviour of an object during influence by agents”. ”Performance” are functional properties. Reference to CIB Master List 1993 and ISO 6241:1984 ”Performance standards in

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building -- Principles for their preparation and factors to be considered" are given for examples of these properties.

A "Function" is defined as "the task an object shall, or is supposed to, fulfil", e.g. "transport", "industry", "office, trade", "health care" and "recreation". These attributes refer to systems composed of both construction objects and users. The activities, or functions, characterise these systems. The Technical Report recommends that these attributes are used for classification of construction entities, which has also been done in ISO 12006-2 (ISO 2001) and the Swedish BSAB System (Svensk Byggtjänst 1998).

"Material attributes" describe the "integral material and molecular structure" of an object. A reference is made to CIB Master List 1993 and the material properties mentioned there, e.g. weight, density, surface structure, etc. These are Compositional properties.

Finally, "Other attributes" like "identification" and "conditions" are mentioned. The importance of the possibility to assign status to a property is pointed out, e.g. "as required", "as designed" and "as built". These properties belong to the main class Administrative properties.

The ISO/TR14177 lacks Phenomenal and Symbolising properties, which means that neither the feelings of a user in relation to a construction object, nor its meaning can be expressed or related to the material properties of the construction object.

EPIC II

EPIC is an acronym for Electronic Product Information Co-operation Group. The co-operation aims at establishing an international classification of construction products to be used in construction product databases (EPIC 1999). Version 2 of the standard includes both a classification of products and a classification of properties of products. The attribute structure from the CIB Master List 1993 is recognisable, but similar to this, the character of classification is weak.

IFC PropertySets

IFC, the Industry Foundation Classes, is an international standard for transfer of information in building product models between information systems IAI (IAI 2002). IFC is developed by the International Alliance for Interoperability, a member based global interest organisation. The standard is developed through member-financed projects.

In IFC, *objects*, *relations* and *attributes* are the three basic entities. Attributes are associated with objects through relations. The most generic entity for attributes is the IfcPropertySetDefinition. It has two subclasses, IfcPropertySet, which can be determined "dynamically" by a user of IFC, and IfcProperty, which has an explicit definition within the standard.

As the user defined, dynamic parts of IFC are extended, a growing number of attributes will be defined explicitly within the standard. At present, in IFC 2.x, there are about 300 attributes defined (IAI 2001). The explicitly defined IFC attributes, which belong to the standard, have been compiled in an alphabetically ordered list in the IFC 2x Property Set Development Guide (ibid). Still, a classification to structure the attribute list is missing.

The IfcPropertySets in IFC 2.x are to be seen as prototypes and not as complete property specifications. They are not complete or many enough to render a classification necessary. However, future more comprehensive specifications will need a more systematic account, among others to allow computer based information management.

Example of classification of properties of construction entities

This section presents an example of how the proposed property classification can be applied to properties of construction entities. The classification is not claimed to be complete or applicable in practice. The objective is to illustrate the use of the proposed classification structure. Under the main classes are examples of sub-classes and attributes.

1 Functional

The subclasses below are taken from the European Construction Products Directive (Council Directive 89/106/CE 1988).

Mechanical resistance and stability: *deformation*

Safety in case of fire: *fire resistance*

Protection with regard to hygiene, health, and the environment: *susceptibility to growth of fungi*

Safety in use: *accident protection, e.g. to exposure of electric current*

Protection against noise: *sound insulation*

Energy economy and heat retention: *thermal transmittance*

Additional functions have been added in the Swedish application (SFS 1994):

Suitability for use: *space layout efficiency*

Accessibility for disabled: *wheelchair accessibility*

Water resource conservation, environm. responsible waste handling: *sewage cleaning effectiveness*

2 Comparative

Geometry, shape: *length, volume, cylindrical, spherical*

Position: *right, left, above, below*

Temporal properties: *completion date, construction period*

3 Compositional

Intrinsic properties: *composition, material, mass, weight, density, elasticity*

Intrinsic process properties: *movement, radiation, emission, bio-degradation*

Production properties: *prefabricated, in-situ produced*

Maintenance properties: *clean, accessible, maintained*

4 Phenomenal

Objective perceptions: *colour, loudness, brightness*

Subjective perceptions: *comfort, beauty, safety*

5 Symbolising

Linguistic: *texts*

Non-linguistic: *signs*

6 Administrative

Identification: *name, ID*

Classification: *BSAB class, architectural style,*

Description: *work specification, guarantee, certificate*

Economical: *price, taxation value*

Conclusions

The result of this study is a proposal for classification of generic properties of systems on the basis of a well-founded theoretical framework. The classification has been applied to develop a classification of properties of construction objects.

The main classes of system's properties have been related to earlier work in construction property systematic. The result confirms some earlier work but also points out shortcomings of these. For example, phenomenal properties and symbolising properties are not among the categories mentioned in earlier classifications. In this proposal all functions are collected under Functional properties. The division into Requirements, Performance and Function classes in the reviewed systems is made for reasons of presentation, and should not be regarded as a classification.

Applications of the proposed classification may show that a further subdivision of the main classes probably will vary, depending on the specific kind of system's properties that are classified. For example the material properties of social organisations are much different from those of building elements. However the main classes may provide a useful start in any property classification.

A hypothesis worth testing is whether the possibility to determine the value space of an attribute depends on whether the system is known or not. For example the colour values of the NCS-system are determined on the basis of human colour discrimination, which is not relevant for all organisms.

The proposed classification should be tested to structure attributes in the IfcProperty list, in CAD-libraries and in web-based product search engines. However, classification of properties gives no guidance to how product properties should be presented to different end users. This must be regarded as a separate problem area. Information must be compiled and grouped in those aspects, which interest the end user.

The CIB Master List 1993 is developed as a general recommendation for presentation of product properties in documents. These principles are applied, e.g. in the Swedish Building Catalogue, and in EPIC 2. The same principles should be tested for presentation of attributes within IFC, e.g. for IfcPropertySets and for objects like IfcWall, IfcWindow etc.

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