ISO DIS 13567 - THE PROPOSED INTERNATIONAL STANDARD FOR STRUCTURING LAYERS IN COMPUTER AIDED BUILDING DESIGN

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SUMMARY: *Layering is a widely used method for structuring data in CAD-models. During the last few years national standardisation organisations, professional associations, user groups for particular CAD-systems, individual companies etc. have issued numerous standards and guidelines for the naming and structuring of layers in building design. In order to increase the integration of CAD data in the industry as a whole ISO recently decided to define an international standard for layer usage. The resulting standard proposal, ISO 13567, is a rather complex framework standard which strives to be more of a union than the least common denominator of the capabilities of existing guidelines.*

A number of principles have been followed in the design of the proposal. The first one is the separation of the conceptual organisation of information (semantics) from the way this information is coded (syntax). The second one is orthogonality - the fact that many ways of classifying information are independent of each other and can be applied in combinations. The third overriding principle is the reuse of existing national or international standards whenever appropriate. The fourth principle allows users to apply well-defined subsets of the overall superset of possible layernames.

This article describes the semantic organisation of the standard proposal as well as its default syntax. Important information categories deal with the party responsible for the information, the type of building element shown, whether a layer contains the direct graphical description of a building part or additional information needed in an output drawing etc. Non-mandatory information categories facilitate the structuring of information in rebuilding projects, use of layers for spatial grouping in large multi-storey projects, and storing multiple representations intended for different drawing scales in the same model.

Pilot testing of ISO 13567 is currently being carried out in a number of countries which have been involved in the definition of the standard. In the article two implementations, which have been carried out independently in Sweden and Finland, are described.

The article concludes with a discussion of the benefits and possible drawbacks of the standard. Incremental development within the industry, (where ”best practice” can become ”common practice” via a standard such as ISO 13567), is contrasted with the more idealistic scenario of building product models. The relationship between CAD-layering, document management product modelling and building element classification is also discussed.

KEYWORDS*: CAD-system, layering, standardisation*

1. **BACKGROUND**

The use of CAD-techniques in building design has increased rapidly during last 10 years and is today common practice for producing building documentation. As a consequence of this, the need to transfer CAD-information between the different participants in a construction project in digital form, and not only as plotted paper drawings, has become of vital importance. In contrast to the layout and symbols of paper drawings, which in most countries is more or less standardised, the techniques for managing digital CAD-data are still in their infancy. A representative of a major Swedish design company recently jokingly remarked, that in major projects the specifications for information co-ordination now seem to be more voluminous that the design specifications themselves. This remark is a clear symptom of the problems caused by the lack of standard data structures for information management in integrated CAD design.

The transfer between CAD-systems of the graphics contained in output drawings alone, which to some extent can be handled using standards such as the DXF-format, is not enough. Increasingly CAD-systems are used not as digital drawing-boards, but for managing integrated 2-D (or at best 3D) models of a complete building. (Excellent guidelines for end users and application developers have for instance been produced in Denmark [Abb 1993]). A system such as AutoCAD makes a clear distinction between model-space (containing the model of the building in world coordinates) and paper-space (containing output from such models in drawing sheet coordinates). As a consequence a prerequisite for efficient data transfer and sharing is that the information in such models must be structured and partitioned in standardised ways. In current CAD-practice quite elaborate layering schemes, often used in combination with the reference-file technique, provide the dominating method used to achieve this end.

In layering systems each drawing primitive is assigned to some layer. The user can then interactively decide which layers to show actively on the screen or to output on a plotter. Figure 1 illustrates this principle.

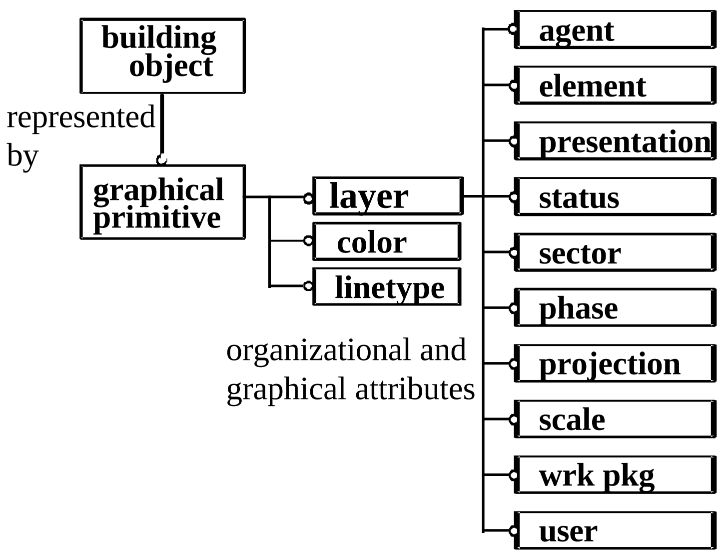

Figure 1. The way in which information is attached to graphical primitives using the proposed ISO standard

Layering techniques were taken into use in the beginning of the 1980's [Port 1984]. Early systems contained a limited number of layers (typically 64 or 256), but nowadays the flexibility is greater. Different CAD-vendors have implemented layers slightly differently but the basic ideas are the same. The benefits of allocating different layers to the different design subdisciplines became evident early on. In very crude layering schemes the architect was for instance given layers 0-99 to work with, the structural engineer 100-199 etc. More sophisticated systems can be based on using national building element tables as a basis of the layer division.

User groups for particular CAD systems, individual bigger projects, large companies etc. have defined their own layering standards. Since the end of the 1980's national standards or guidelines had been developed in a number of countries [NSF 1992] , [AIA 1990], [BSI 1990]. In some countries (i.e., Sweden) the market dominance of particular CAD applications for building design has provided de-facto standards. Although most of these standards seem to use quite similar basic principles for layer division, the implementations and syntaxes vary a lot and make data exchange difficult. Many of these standards also suffer from technical deficiencies resulting from the ad-hoc and incremental fashion in which they were developed.

This is the background for the decision of the committee TC10/SC8 of the International Organization for Standardization to appoint a new working group ISO TC10/SC8/WG13 with the scope of defining an international standard for the use of layering in construction [ISO 1990]. The committee had its first meeting in Stockholm in October 1993 and a Draft International Standard was approved in September 1996 [ISO 1996 a,b], [ISO/TC10/SC8/WG13 1996].

2. PRINCIPLES FOR THE DESIGN OF THE STANDARD

One problem in analysing and using the different national layering standards and proposals, which were included as background material for the work of the committee, is the ad-hoc way in which these standards have evolved and are presented. One of the first steps in the design of the overall structure of ISO 13567 was thus to clarify the fundamental principles which should be used in the construction of the standard. Based on an early analysis four principles were adopted. These are:

- separation of semantics from syntax
- orthogonality
- reuse of existing national or international standards
- possibility of using well-defined subsets

2.1 Separation of semantics from syntax

The most important lesson which can be learnt from the modelling work currently being done in other related standardisation efforts, such as STEP [Owen 1993], is the value of a clear separation of semantics and syntax.

The organisation of the standard is based on a fundamental principle of database design - the clear ***separation of the logical organisation of information (conceptual level) from the way this information is coded in particular CAD layer naming implementations (internal level)***. For a description of this principle, see for instance [ISO 1985]. The primary focus has thus been on defining a clear organisation of information describing a building which fulfils the functional requirements of the information users. The first priority was thus to decide which information categories should be used for determining the allocation of graphical elements to layers. The syntax, i.e. coding scheme for layer names, was considered a secondary issue. For each solution on the semantic level there are numerous possible syntactical solutions. In practice is seems that the syntax of layer names has often been limited to 8 characters, which may have caused unnecessary restrictions also on the semantic solutions chosen.

A default syntax using a fixed length format is, nevertheless, included in the standard. This was deemed necessary due to the fact that end users and vendors seem to expect one proposed syntax (most earlier standards have one). If this syntax is used it also facilitates data exchange. It should, however, be stressed that the semantic structure of the standard could be easily implemented in many different ways (for instance including reference files and their file naming or using variable length syntax’s with delimiters). In such cases the necessary requirement for a syntax to be permissible is that it is possible to unambiguously translate layer names back to the default syntax and vice versa.

2.2 Orthogonality

A second overriding principle is ***orthogonality - the fact that many ways of classifying information are independent of each other and can be applied in combinations***. A simple example of orthogonal classification would be the classification of citizens of a country by date of birth, sex and place of birth (Figure 2). Every citizen can be classified according to each of these three criteria, and the classications are independent of each other. In traditional classification systems this principle has often been called faceted classification [ISO 1994](used for instance in the original SfB system, cf. [CIB 1986]). The same principle has also been used in some generic product data model proposals [Gielingh and Suhm 1993].

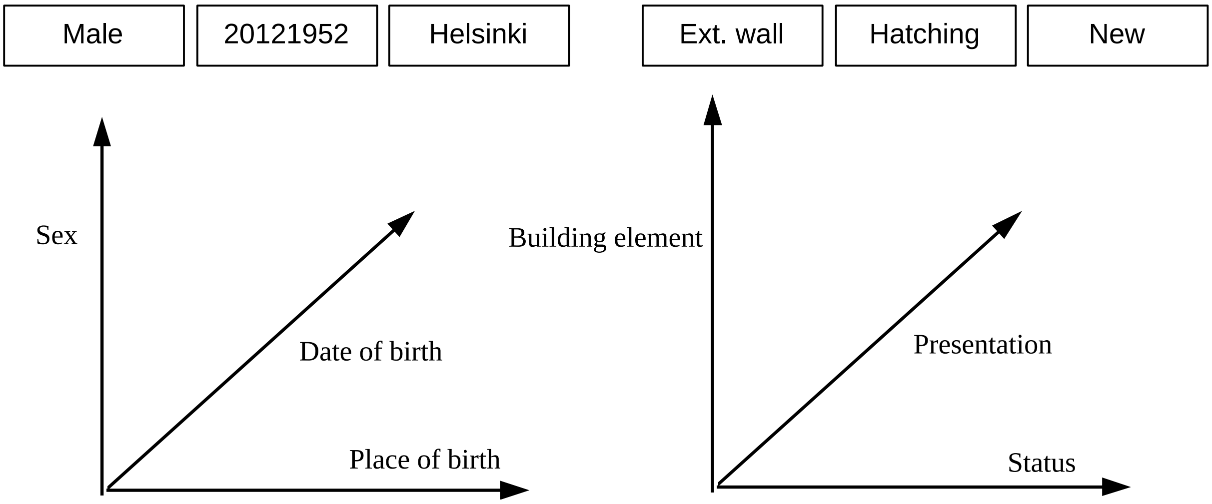

Figure 2 The basic idea of orthogonality applied to data about a person and about a layer.

In order to achieve orthogonality, information of a different nature should be placed in different parts of the layer name. Among the benefits of this is that it is easy to split up the information in a CAD model according to different principles. The principle of orthogonality has often been violated in current layering schemes, for instance by using sequences of unused numbers in an existing building elements table for denoting information related to the graphical outlook of drawings. An example of this can be found in the Norwegian standard NS 8351 [NSF 1992]: The national element classification uses codes 2 through 7. In the layer names code 0 has been used for “combined layers”, code 1 for existing situation, code 8 for drawing elements and code 9 for “support layers”. This coding makes it impossible for example to divide or handle the existing situation or support layers according to building element.

2.3 Reuse of existing national or international standards

A third principle is the ***reuse of existing national or international standards whenever appropriate***. This is motivated by purely pragmatic considerations. An international standard which would try to override existing national conventions for the naming of floors in a building or elemental classification codes would cause a lot of resistance and would also result in a data structure which is incompatible with important downstream uses of CAD data, for instance in cost estimation packages which often are based on national classification tables. As long as there are no internationally agreed classification tables for building elements, most applications of the standard will resort to using national classification tables.

The negative consequence of this is that the different applications will be partially incompatible. But by a strict use of the orthogonality principle it should be possible to contain these incompatibilities as much as possible within well-defined bounds and to solve them by conversion tables for individual fields in the layer name.

2.4 Possibility to use well-defined subsets

The fourth principle which has been followed is the use ***of well defined subsets of the overall potential space of layer names.*** Experiences with the IGES standard in the 1980's indicated that the standard had become so large and complex that few CAD-vendors implemented all features of the standard in their translator software. As a consequence translations between different CAD-systems often lost data due to the incompatibilities between the "subsets" that had been implemented. For this reason some development work was undertaken of IGES subsets for the building sector. The current overall architecture of the STEP standard, which supports implementation of a sort of subsets (in the form of application protocols) of the overall voluminous resource models, is also a variation on this principle.

In the case of the layering standard, the subsetting principle is implemented by making some of the overall information categories optional as well as by allowing the end user the choice of which of the mandatory specific layer codes (defined for some cases) he actually uses. The actual structure of the codes is also such that a sort of ***generalisation - specialisation principle*** is followed. For instance in the case of codes for the information category presentation, the end user can choose between a cruder split of information or a more granulated one. It is thus always possible to translate information from the more detailed level to a more general level. For the case of the building element category, the codes of the national building element classifications in most countries are constructed in such a way as to allow the implementation of generalisation - specialisation.

3. SYNTAX OF THE STANDARD

In principle, the semantic content of the standard could be represented using several alternative syntaxes. Below some of the possible choices are presented:

- Sequential numbering of layers
- Alphanumeric list with fixed-order fields
- Alphanumeric list with free-order fields

In sequential numbering the layers are numbered in strict sequence from 1- N, where early systems often had upper limits of 64 or 256. This minimised the memory space needed to store the layer attribute. However, layer names were difficult to understand and conversion tables were needed.

The currently most common type of layer naming offers an almost unlimited number of possible layers by using characters strings of fixed length. In some systems there is a limitation to 8 characters, but some offer longer names. The layer convention of the American Institute of Architects, for instance, offers both a short (3-8 characters) and a long name (6-16 characters) (AIA 1990). Usually, specific fields within the layer name are reserved for specific information types. The benefits of this are that it facilitates direct human interpretation. Additionally the length of each field is usually fixed so that no space needs to be used for delimiters. Some simple search strategies for groups of layers (i.e. wildcarding) are also easy to implement.

Alphanumeric lists with free order could also easily be implemented. The benefit of this is that in a particular implementation space would need to be allocated only for those information categories which are actually used. The drawback is that the codes wouldn't be as easily human interpretable. It should however be noted that the value of human interpretable layer names is decreasing as user interfaces for layer management get better. In such user interfaces layer names get explained with full text explanations, pull down menus etc. rather than as "raw" code strings.

The choice of the recommended default syntax for the ISO standard was dictated by pragmatic reasons. There was strong pressure for fixed-order fields since most existing standards are implemented this way. Additionally there was some pressure to limit the length of the mandatory fields to eight characters since such a restriction exists in some CAD-systems. In the end, this restriction had to be relaxed due to pressure for lengthening the element code from four to five characters. Figure 3 shows an example of permissible layer names coded using the default syntax.

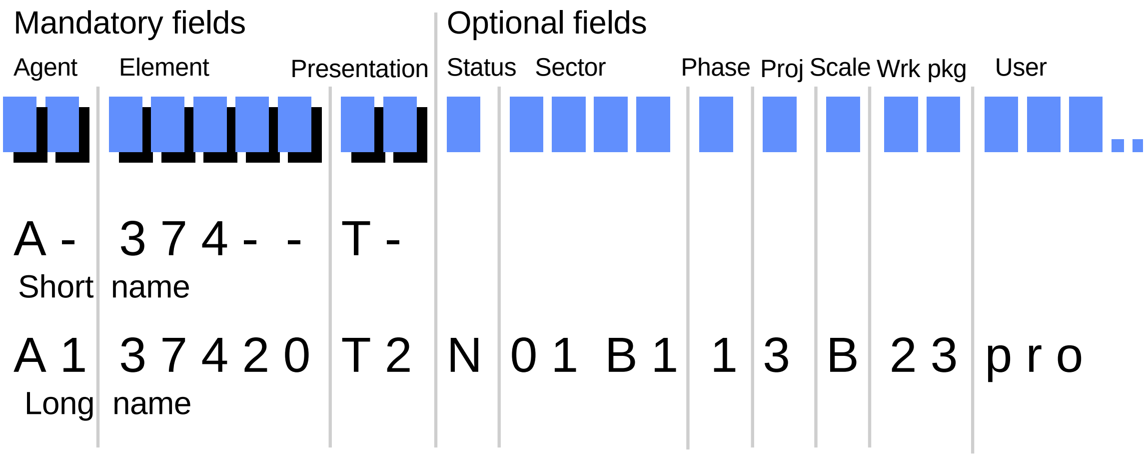

Figure 3. Layer name syntax with examples using mandatory fields only or all fields.

4. STRUCTURE OF THE STANDARD

4.1 Overall structure

In the following paragraphs, the categories of information that were included in the standard are presented.

Within the standard, there is a clear priority order for how particular codes (and thus also the underlying semantic categories) can be defined.

- A particular code is already defined in the ISO standard
- The codes are determined in some national standard
- The codes are agreed to on a project basis

Where reserved codes are given, they shall be used only for the purpose and value specified. Codes other than the reserved ones may be used for project-specific values. Even if the codes are predetermined the user is left the option of deciding which subset he wishes to use in a particular project.

4.2 Agent Responsible

This information tells which party (of the participants in a construction project) is responsible for the information. Since there is a multitude of possible classifications, depending on the type and organisation of the project at hand, no classification is included in the ISO proposal. Instead, such classifications can be further specified in national standards based on ISO13567 or project-specific agreements.

Table 1 shows an example of a possible classification by agent responsible, taken from the Swedish implementation Bygghandlingar 90 (SIS 1996).

Table 1. Codes for agents, as used in the Swedish CAD guidelines Bygghandlingar 90 (SIS 1996). The second character should be used to distinguish multiple agents or assignments within the same discipline.

Content	**Code**
Architect	A-
Architects 1 and 2 (on the same project)	A1,A2
Electrical engineer	E-
Interior architect	I-
Structural engineer	K-
Landscape architect	L-
Civil engineer	M-
Project management	P-
Special consultant	S-
HVAC engineer	V-

4.3 Element

Classification tables for the functional parts of a building have been defined in many countries and are used to structure building specifications, bills of quantities, library information, etc. In many existing layering conventions such classification tables have formed the backbone of the layering schemes. A serious problem is, however, that no international classification has emerged. For this reason the ISO-standard refrains from defining such a standard and allows any nationally defined or project-specific element breakdown, provided that it is well documented.

From a CAD-viewpoint, a serious deficiency in many existing element tables is that they lack a category for pure space. If this is the case the recommendation is to add such a category. In order to fulfil the orthogonality principle, categories in national element tables which by their nature are work packages or are related to the process (demolition work) should be avoided.

Table 2 shows some possible codes taken from the Swedish implementation by FFNS Gruppen.

Table 2. An example of codes that can be used in the element field, based on an adaptation of the Swedish building element classification system BSAB96. Note in particular that a code for spaces has been included in the classification.

Content	**Code**
Landscape,general	100
Building, general	300
Loadbearing walls	331
Roof	340
Exterior walls	350
Openings in exterior walls (doors, windows etc)	355
Interior (non loadbearing) walls	363
Suspended ceilings	364
Stairs	366
Interior surfaces	370
Spaces	900

It is noteworthy that, since no mandatory element breakdown is stipulated in the ISO standard, the standard could equally well be used as the basis for layering standards for other large-scale engineering products, such as bridges, process plants, roads, ships, off-shore platforms etc.

4.4 Presentation

The information contained in a large integrated CAD-model can be broken down into two fundamental categories; information which is directly related to the model in world co-ordinates of the building, and information which is added to different output drawings in order to enhance readability.

The first category includes the direct representation of the geometry of building parts (i.e., outlines of the sides of a wall) or symbols that in an abstract way represent such parts (i.e., the symbol for a light switch). The second include drawing borders and headers, schedules, etc.

Since the subclassification within this domain is relatively stable from one CAD-system to the other and from one country to the other, the ISO standard contains a mandatory classification, which is shown in table 3.

Table 3. The reserved codes for the first character of the presentation field. The indentation indicates the hierarchical structure of the classification.

Content	Code
Whole model and drawing page	--(two hyphens)
Model	M
Element graphics	E
Annotation	A
Text	T
Hatching	H
Dimensions	D
Section/detail marks	J
Revision marks	K
Grid	G
Graphic	Y
Dimension	Z
User	U
Redlines	R
Construction lines	C
Page/paper	P
Border	B
Border lines (Frame)	F
Other graphics	O
Text	V
Title	W
Notes	N
Tabular Information	I
Legends	L
Schedules	S
Tables (Query)	Q

The proposed classification is open-ended in the sense that it is possible for the user of the standard to create further subclassifications of the prescribed classification. The second character of the presentation code, which isn’t specified in the ISO standard, can be used for this purpose. A good example is the envisaged way of using T1, T2, etc. to denote text in different langauges (a facility which could be useful in multi-lingual projects). On the other hand, a user may decide not to use the full granularity of the prescribed codes but to use them on a coarser level (for instance using only the codes M- and P-). Altogether such uses provide a good example of the generalisation-specialisation principle mentioned earlier in section 2.4.

4.5 Status

The study of existing layering schemes revealed that some contain features for dealing with demolition work, but often on a cruder level than for new construction. Whereas a full elemental breakdown can be applied to building elements to be constructed, sometimes only one code may have been reserved for any kind of demolition work.

In the ISO standard the idea of classifying information according to whether a building part is to be demolished or built has been retained, but it has been treated as a separate "facet". The stipulated classification is shown in table 4. This results in a much more powerful mechanism which allows the modelling of the situation before and after rebuilding of existing facilities in the same model. It is for instance possible at a glance to view all partition walls which are to be demolished, or all new walls to be built.

Table 4. The reserved codes for the status field.

Content	Code
(no subdivision)	-
New part	N
Existing to remain	E
To be removed	R
Temporary	T
To be moved, Original position	O
To be moved, Final position	F

4.6 Sector

Since layers are used to structure full building models in 2-D the layering facility is often used to split the information according to which storey in the building it pertains to. For some purposes there may also be a need to separate information depending on which part of a building it is related to.

Since the standards for coding storeys may vary slightly from one country to the other (which is the "first" floor?) no mandatory classification is proposed.

4.7 Phase

Sometimes it may be useful to use the layering facility to split up information according to the phases of a project, for example in project management. Such a classification is, by necessity, project specific.

4.8 Projection

In 2-D CAD, the CAD-model is used to store one or several projections of a building, rather than a full 3-D model. The three main projections (plan, section, and elevation) can be split into independent models, but for dimensional co-ordination purposes it can also be useful to store them in the same model. In such a case, it is useful to be able to use layering for splitting up the model into these categories.

4.9 Scale

A common misapprehension among lay people is that the information contained in say a 1:50 or 1:100 drawing can be obtained simply by blowing up a 1:200 drawing. For some information categories this may be true, but in many cases the geometrical or symbolic abstractions used to represent the same building elements look quite different in different scales (Figure 4).

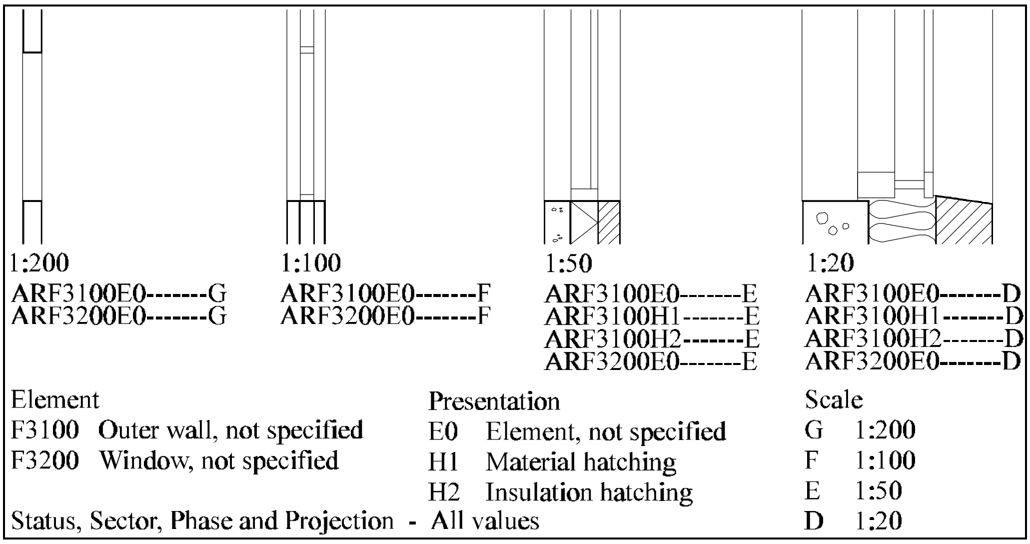

Figure 4. Detailing for different scales stored in separate layers

These different representations of the same parts share some properties, such as location points. In particular output drawings only one alternative is usually shown, but in the full model it is useful if all of these can be included in the same model, rather than having non-integrated separate models for drawings at different scales.

The layering facility can be used to facilitate the storing of presentations related to different scales in the same model, and such a classification has been included in the standard. Since the scales used in construction documentation are well known (and have in fact been standardised by ISO) it has been possible to prescribe the scale alternatives included in the layer standard.

This information category could be very useful for instance for the manufacturers of building components, who may wish to build up libraries of standard CAD-details.

4.10 Work package

In addition to the subdivision of building parts according to their function, it may be useful to have a subdivision according to the type of activities needed to produce the parts (work package). This subdivision is often oriented towards material, or product categories. Work package codes can be based on national tables, which exist in some countries, or be project-specific.

4.11 User defined

In any standard with such an ambitious scope as this one it is prudent to include a separate information category for some use which the standards writers didn't anticipate or didn't consider important enough to include as a specified category.

4.12 General comments

Of the above categories, only the first three (agent responsible, element and presentation) are mandatory. All other categories are optional and the decision whether or not to use a category can be done at the project level. During the design phase the three mandatory categories, complemented by the status category, are often sufficient.

Even if only mandatory information categories are used, the standard leaves a lot of choice to the end user. The responsible agent breakdown is always project specific. An existing element breakdown can be used at many different levels of detail, and only a subset of the presentation categories can be used, etc. Thus, an implementation with as few as 20-30 actually-used layers at one end of the scale or an implementation with thousands of layers at the other can both be in compliance with the overall framework of ISO 13567. One of the benefits of using the standard is that it should be possible to generate different implementations from the same CAD software simply by switching the files which list the different subcategories to be used within each information type. Another important aspect is that it should be possible to transform layered CAD-models from a more complex scheme to a simpler scheme by merging layers into layers higher up in the hierarchy (generalisation).

5. PILOT IMPLEMENTATIONS

5.1 Need for testing

The ISO standard proposal may at a first reading seem highly complex in its structure. However, it is possible to define relatively simple applications which still are in compliance with the standard. For this reason it is extremely important that pilot projects be carried out as soon as possible to provide demonstrations of the use of the standard. At the same time, such pilot projects should provide feedback on the benefits and possible drawbacks of the project, as well as provide information about changes and amendments needed in future revisions.

In the following pilot implementations in two countries, Sweden and Finland, are described. In both countries the organisations in charge of building standardisation are in the final stage of a process of defining national implementation of ISO 13567. In these, more specific codes for certain information elements, such as building elements, have been defined.

5.2 Swedish implementation experiences

5.2.1 Background for the implementation

FFNS Gruppen AB is a large consulting company comprising building and interior architecture, structural engineering, planning and landscape architecture, as well as project management. The company has about 500 employees on 24 locations in Sweden and 4 locations abroad.

The goals of the overall company-wide IT strategy are three-fold:

- to facilitate cooperation between experts within the company regardless of physical location.
- to improve information exchange between all parties involved in a project.
- to enable the re-use of proven good solutions in new projects, building a “company library of experience”.

All three goals demand a common information structure that should be easy to use for personnel with varying knowledge and experience of CAD. The information structure should also be such that it could cope with different software used by other companies that FFNS cooperates with in design projects. As part of the strategy for model-oriented CAD, an internal layering standard based on ISO 13567 has been defined and tested with real data. In the first phase, the layering application is focused on architecture and structural engineering for buildings, and introduction is restricted to the branches located in Sweden.

5.2.2 Adaptation of the ISO standard

The project was carried out by a group of experienced CAD users and developers, representing the different design professions. Present needs to structure CAD information, both for design and construction as well as for facilties management, were analysed. The layer structure of current application software was also analysed and compared to the needs that had been identified.

The analysis of needs and existing applications resulted in a decision to use the three mandatory fields of the ISO standard as well as one of the optional fields, Status. A uniform, 10-character layer name is thus used in the FFNS application (Figure 5).

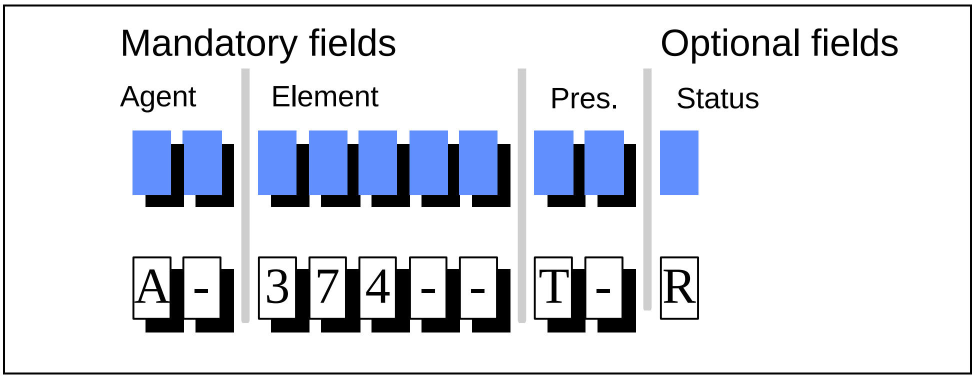

Figure 5. Layer syntax of the FFNS application.

The *Responsible Agent* field uses codes for the first character according to a national standard for abbreviation of technical consultants, etc. The second character is used to separate information for separate assignments to the building owner and tenants respectively, even if they are carried out by the same architect or technical consultant.

Codes for *Elements* use national classification tables (BSAB system, table P2). This is a hierarchic system based on the functions of elements, such as load-bearing, room-dividing, or climate-protecting. As a consequence, walls, doors, windows, etc. have different codes depending on their “main” function. Often, this is not suitable for the presentation of drawings. Therefore, when applying the codes, a code high up in the hierachy has often to be used, and complemented by additional coding for “secondary” function. As a rule, the three first characters are original BSAB code, while the following two are used for additional subdivision. Codes for spaces, which are not supported by the national classification, have been added. Space information has also been classified according to function, e.g., rooms, apartments, fire protection zoning.

The FFNS application contains the reserved codes of ISO 13567 for the first character of the *Presentation* field. An additional presentation subdivision, which uses the second character, has been added for several categories, the most important ones being different kinds of text (see Table 5), hatching, and information belonging to the drawing sheet.

Code	Content	Remark
T-	Text, general	Text not subdivided for presentation purposes
T1	Name	Classifier (e.g., room name)
T2	Number	Identifier (e.g., room number, type code)
T3	Quantity	Amount, area, volume

Table 5. Presentation codes for text in model space

The *Status* field uses the reserved codes of the standard to denote the status of building elements, mainly for the purpose of facilitating the production of demolition drawings. Due to the increasing portion of renovation and refurbishing projects the status field is considered to be important.

Subdivision according to the remaining optional fields of the standard were not in general use at the period of testing. Some of the fields, e.g. *Sector* and *Scale*, will probably be added in specific projects where there is a demand for more complex CAD models, as well as additional subdivision by application of the *User* field. One example of the latter is the origin and quality classification of geometric data for existing buildings.

5.2.3 Development of prototypes

Prototypes were developed, based on AutoCAD and the Swedish AEC application Point. In the resulting applications the structuring of information in layers has been combined with a model-oriented approach to 2D CAD. Documents are produced using file references with a model space/ paper space system. All information is stored on file servers in a company wide network. Files are named and placed according to a company standard file system.

A simple user interface, based on prototypes developed earlier by Seamus Gilroy, member of the ISO working group, was designed for the creation and visibility control of layers (Figure 6). From lists of allowed codes for each separate field, the layer name or group of layers is composed. If this specification results in a layer that is not present in the CAD file, a new layer will automatically be created.

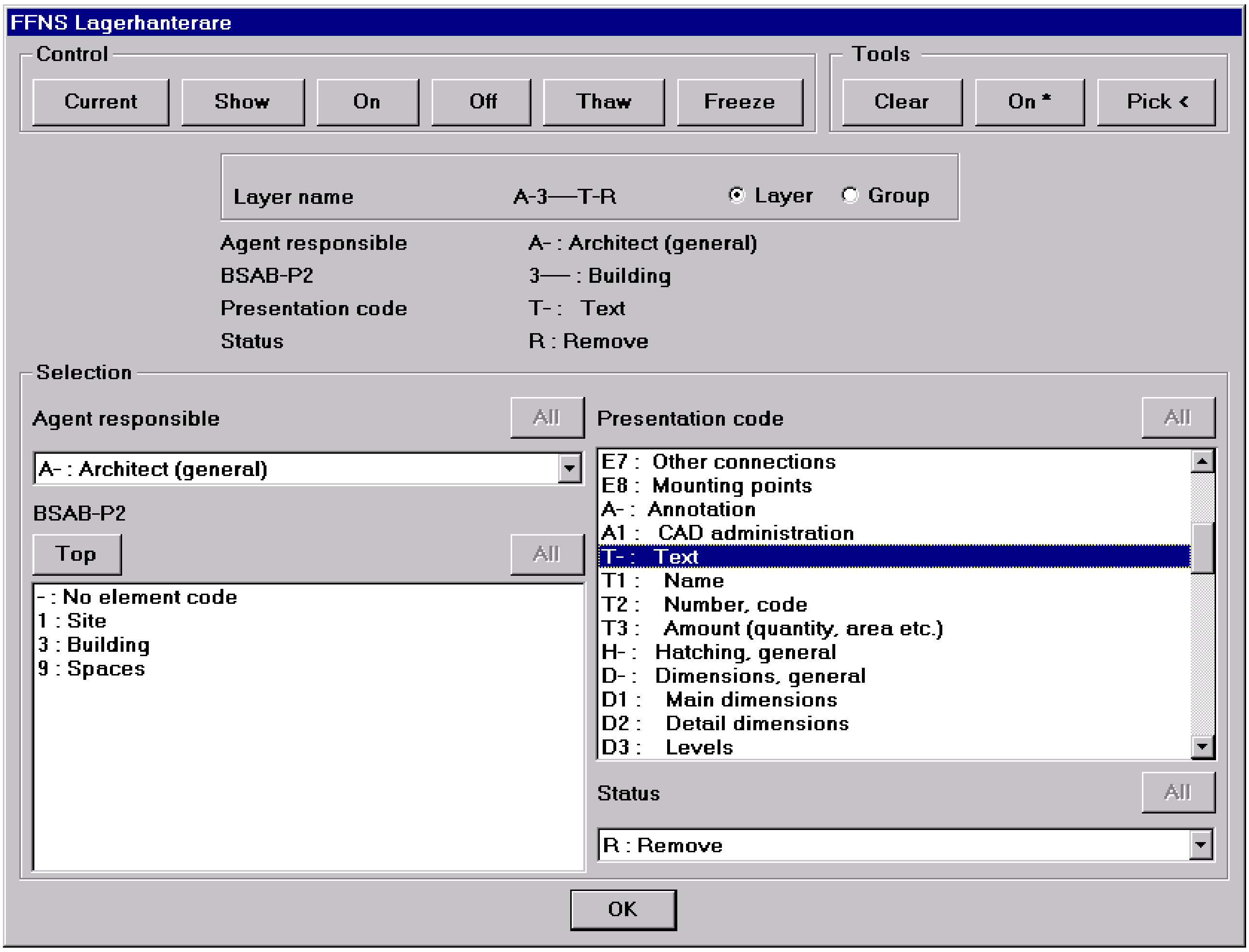

Figure 6. FFNS Layer Manager dialogue box

When designing the dialogue, the educational aspect was considered very important. Therefore, the number of functions is quite limited. No courses to educate the CAD users should be necessary. This approach seems to have fulfilled its purpose - the new systems were accepted very rapidly and there were few question about the use. In future versions, more elaborate management of the structure will probably be introduced.

In addition to the Layer Manager, automatic assignment of layers has been embedded in all functions of the AEC application program, and conversion programs from the previous layering structure and back are available to the user.

5.2.4 Testing of the prototypes

The proposed layer structure was tested using data from a real project. The plans for a hospital wing were chosen as they were considered to be sufficiently complex for the purpose (Figure 7). The layering structure of the CAD-files was converted from the old system to the new one. Conversion was done using macros for mapping the layer structures to each other, and then manually refining the layering using the new structure.

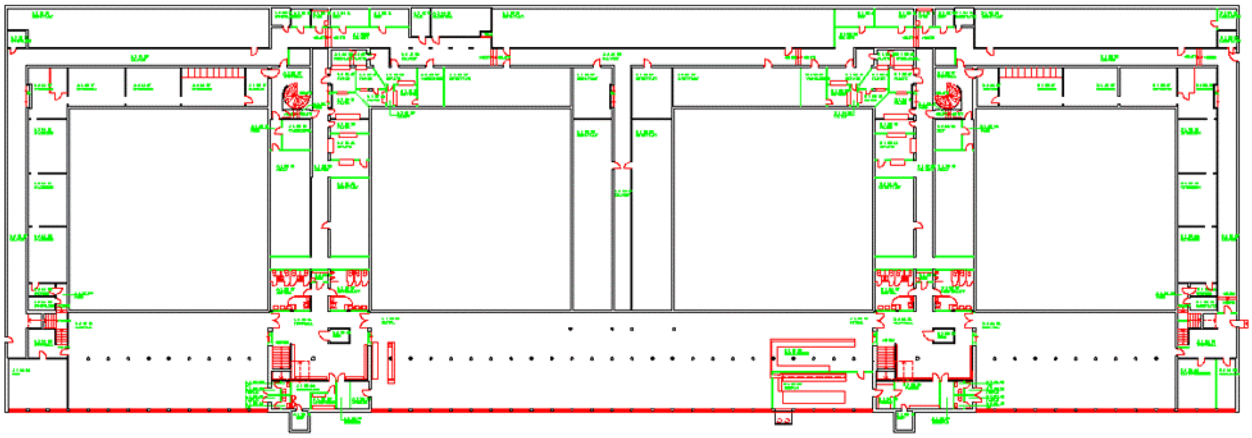

Figure 7. Building plan of test project

Very few problems occured in the mapping process, mostly due to the way the layer tables had been designed, taking into consideration the layer structure of the previously used application as well as the desired structure. The conversion from the old structure, means that further subdivision has to be done manually in order to arrive at the full functionality of the new structure. This additional subdivision is of course lost in the case of a conversion back to the old structure.

Further comparison between layering tables of various applications has been done, and show that there is a similar compatibility between the proposed tables and most applications for building design. Information exchange with applications for special purposes, such as airport and road design, require more extensive manual processing. This indicates a problem that goes far beyond layering, namely reconciling the different views on information, seldom explicitly stated, that constitute a barrier between those who design, build, and manage a building respectively.

The tools for handling separate layers as well as logical groups of layers have proven useful to identify and correct the placing of elements on different layers. Previously this has often been a problem in all those cases where application software cannot automatically dedicate information to the appropriate layer.

The number of layers used in a project are not nearly as many as the standard allows. Standard layer lists, which are loaded with every new CAD file, contain about one hundred layers. These are the layers found to be currently used in order to control visibility on drawings and on screen.

5.2.5 Feedback

As already mentioned, the new layer structure was introduced as part of a model-oriented methodology where structuring of a project file system and of model/drawing files are the other two main parts. The introduction of the methodology to the employees has been supported by a “CAD Methods Manual” covering all three parts.

The manual was meant to be the only instruction to the new methodology, and contains a substantial portion explaining the fundamental concepts. In the case of the layering part, this method proved to be successful, but additional education was found necessary to support the paradigm shift from drafting to model-oriented CAD.

The feedback from the first months in use indicate that:

- The application based on the ISO standard is readily accepted by users - clarity in structure is appreciated (as opposed to most earlier applications developed by vendors).
- The layering method can be introduced with self-education supported by tools that help the users understand the structure.
- Clients are interested. As better use of information structuring in design partly depends on customers starting to make such demands, this interest may be the platform for better integration in the construction and facility management process.
- The ISO standard is easy to adapt to national and company-specific conventions. Structuring problems were mainly found in applying national classification systems not suited for (and originally not intended for) CAD applications.
- There are lots of personal views on the codes and structures of the presentation field. This concept is not homogenous, and the different aspects that are included cannot easily be combined into single codes.
- An application interface is needed to handle the layer name. Once this interface is at hand, it is not considered as a problem, since the interface also gives new possibilities.

5.3 Finnish implementation experiences

5.3.1 Background for the implementation

Studio Kivi is a small architectural design practice in Helsinki. CAD-systems have been used by the Studio for a number of years and experts from the firm have participated in national R&D projects as well as in the teaching of CAD-techniques to students of architecture. Studio Kivi has been testing a layering system based on ISO 13567 in several building projects since September 1995.

5.3.2 Adaptation of the ISO standard

Most of the CAD-layering implementations already in use in Finland have in some way utilised the national building element classification system (House 90). In the adaption of the ISO standard, the three first characters (one letter and two numbers) in the element field are consequently directly based on the Finnish standard element code. All five characters allowed for are not always necessary, but can in some cases be utilised. The recommendation is to use numbers as the two last characters, where 00 corresponds to the cases where the element is not specified.

In the presentation field, the possible values of the first character are already specified in the international standard. The second character is, however, open to national or company-specific adaptions. It can for instance be used for different levels of identification needed in different phases and plots of a project (0 = ID-number, 1 = type, etc.). The use of presentation for this purpose works especially well with attributes. This field could be used also for different languages in multi-lingual projects (quite common for Finnish design companies) by using letters (F = Finnish, R = Russian, S = Swedish, etc.). In the testing material suitable projects were unfortunately not at hand to test how useful this feature would be.

5.3.3 Development of prototypes

The prototypes were developed using AutoCAD version 12 for DOS and version 13 for both DOS and Windows.

The actual full layer codes resulting from the ISO standard are not easily human readable. For this reason an application with a user interface which provides full explanations to the layer contents is absolutely essential.

There are several reasons for this demand:

- the visible names must be comprehensible for the user.
- if the user writes the names directly, spelling errors will probably make the structure fail to be program readable.
- the structure of the name and the codes in every field must be checked.
- the new layer names must be recorded automatically for documentation and further use in the project.

An application was developed to fulfill these demands. The basic idea is to have a project database or even a simple ASCII file where each layer name, the color and the description of the use is recorded. When a drawing file is opened the data is read in and each actual layer name and the description is combined. In every possible place on the screen the user sees the description of the layer's usage instead of the code name. AutoCAD's common layer dialog is enhanced with a new dialog (figure 8).

The user can select the layers by their properties - color, element, presentation, status and description - or even a combination of those. When the user wants to create a new layer to the drawing, he can do it using the "Make" button, which gives a list of all pre-defined layers which are not yet in use in the drawing at hand. If a suitable layer does not exist, the next level "Create a new layer" gives the user the possibility to create a totally new layer and also to include it in the project database. All possible element, presentation and status codes and colors are available in the list boxes and the user can write any description to the new layer. All parts are checked before a new layer is accepted.

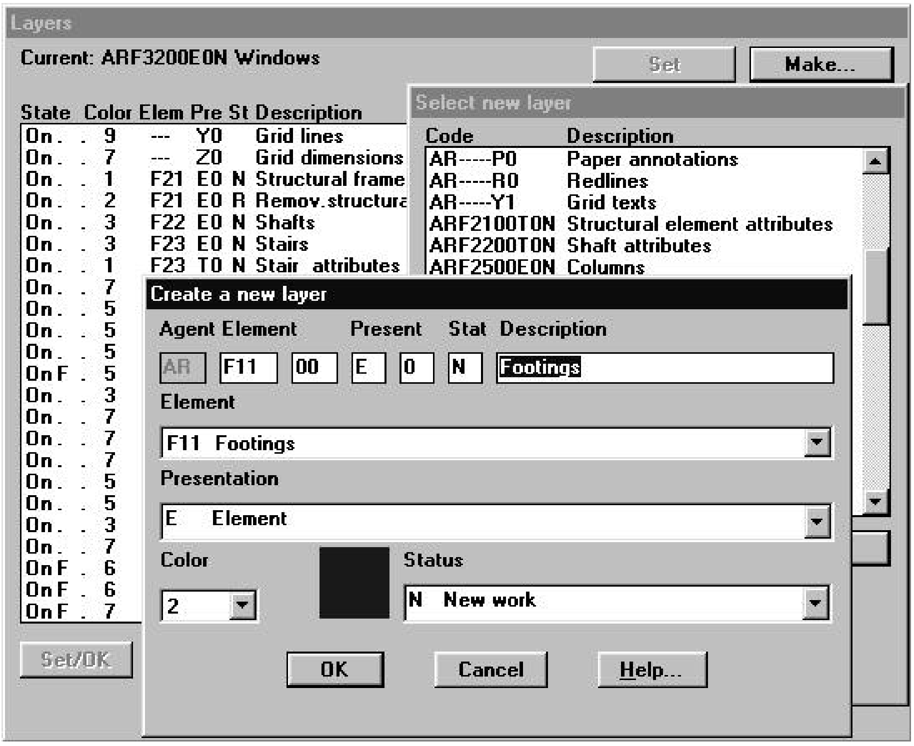

Figure 8. Dialogue for creating new layer

If data from external reference files are used in the drawing, the main dialog box is different. In this way, all layers which have the same actual name even in different drawing files can be controlled. The actual layers in the drawing are shown in their own box. Using this method, a model consisting of for example 20 apartment drawings with 50 layers each is not shown to the user as a drawing with 1000 layers arranged by the drawing names, but as it really is - a logical combination of 20 drawings and 50 layers.

5.3.4 Testing of the prototypes

The prototype implementations have been tested in a number of projects. In the case of the ICL Finnish Headquarters in Helsinki (140.000 m^3), the design work had been half finished using an old layering system. The CAD-files were, however, converted to the new standard for facility management purposes.

Another building which provided suitable data for testing was the University Hospital in Oulu, (600.000 m^3). This existing large building complex was measured and drawn as a CAD-model for facility management purposes by Studio Kivi. Part of this data was structured using the ISO-based standard in order to test the functionality of the standard.

The other test projects were renovations of different types of buildings (and of different sizes): an office building, a hotel, two military buildings, and a warehouse. In some of these projects CAD-files describing the existing situation, in which the original layering system was not in any standard format, could be used as input information. In other projects, the CAD-files had to be produced manually through visual inspection of paper drawings .

In the ICL project the number of layers was about the same in the old and the new system, but the structure was slightly different. The number of graphical layers was decreased by combining some layers, mainly concerning furniture and equipment. The number of layers for different attributes was increased by dividing of some attributes into rooms and doors. All these changes were made automatically and they were requested by the user of the information, not forced by the ISO layering structure.

5.3.5 Feedback

The new layering system was found to offer significant improvements compared to the old Finnish systems, especially in renovation projects. Most current applications are made only for the design of new buildings. The idea of a separate status field is essential for renovations (figure 9). The new work status can also be described by the lack of the status code. In that case the naming system is the same as in new building projects. This method can of course not be used, if no other optional fields are used in the project.

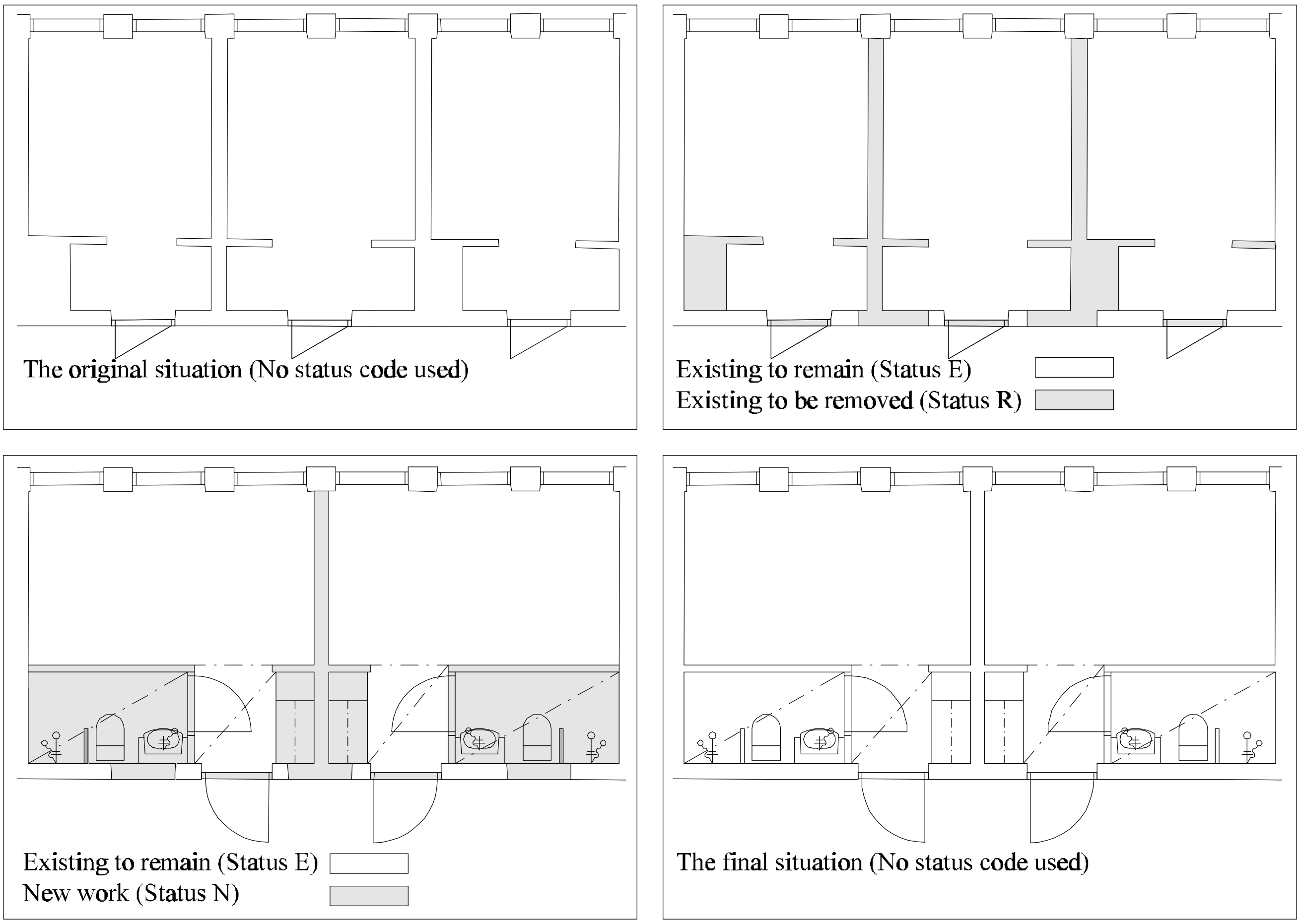

Figure 9: An example of how the status field can be used as a discriminator to produce tailor-made drawings facilitating the design and management of rebuilding.

The presentation field is a new idea, at least in the systematic way in which it is treated in the ISO standard. It makes it much easier to use relevant structures - the main idea of layers is to control the visibility and the presentation corresponds quite well to this ideology.

The translation from old layering systems in use was very ease to arrange, because it is possible to make the accuracy of the new system based on ISO-13567 even more precise. Of course the structure cannot automatically be improved, but the new system does not make any unnecessary limitations to the number of layers or the logical structure.

In the test material seven projects with a total of 40 drawings were included. The total area covered in these drawings is about 125.000 m². In each project the actual layer structure was different. There was no correlation between the number of layers used and the size of the project. The number of layers was, however, clearly affected by the type of the drawing and the design stage, which seems quite logical. The actual number of layers in use naturally depends on the user and the application at hand. In Table 6, there is a summary of these drawings.

Table 6. Summary of drawings and the average number of layers in them

Type	Layers, average	Drawings
Plan, sketch	22	4
Plan, detailed	50	19
Plan, FM	29	8
Section, detailed	17	4
Elevation, detailed	12	2
Site plan, detailed	20	3
Total	36	40

The number of defined layers in each project was 100-140, but only half or even a quarter of them were really used in the individual drawings. Almost half of the drawings were detailed plan drawings, where the average number of layers was 50. At the sketch stage the average number of layers in plan drawings was 22, but only 5-8 of these were actually needed by the user at this design stage. The others were made and imported with the ready-made symbols and their attributes. If the drawings were made for facility management purposes, the average number of layers was 29.

In reading these figures the reader should bear in mind that they concern the layers where the architect is the responsible agent. If the layers of the structural engineer and the different building services engineers are added, the total number of layers is increased 2-3 times.

Some other conclusions of the testing were:

- The creation of new layers must be controlled so that the structure and syntax is checked for correctness. If the users can invent new layer names without any checking system, the system may not work because of the lack of automatic documentation, and the introduction of human errors.
- The end users are willing and able to use a minimised set of layers for their purposes, which also is the sensible way to work
- The documentation of the layer structure in use must be provided in every project and archived with the other documents. The documentation must be made both human and program readable and it must be updated automatically, when a user makes new layers.
- The number of pre-defined layers should be much greater than the number of layers actually used in each CAD-file or model. This is important in order to prevent end-users from inventing their own layers where such requirements can be anticipated in the standard itself.
- The experiences from the projects indicate that, apart from the status field, the other optional information categories of the ISO standard are not usually needed. Consequently they were not tested in the test projects described above.

6. DISCUSSION AND CONCLUSIONS

6.1 Potential benefits of ISO 13567

Compared to current layer practice the proposed international standard offers the following benefits:

- One international standard instead of a multitude of national, user-group and company-specific standards.
- Strict adherence to certain guiding principles (i.e. orthogonality).
- A flexible structure allowing its implementation at many different levels of detail

- A comprehensive coverage of foreseeable user needs (union rather than least common denominator)
- A structure which makes it easy to convert existing layered CAD-data into an ISO-compatible format ("backward compatibility")
- A structure suitable for the later reuse of data in product modelling software ("forward compatibilty").

The first three of the above conclusions are relatively self-evident, given the current state of CAD usage in the industry and the design principles which were used in the definition of the standard. The fourth conclusion (comprehensive coverage of foreseeable user needs) has been a goal of the ISO committee defining the standard and has so far been validated in the testing work in Sweden and Finland. The last two conclusions necessitate some more discussion.

6.2 Backward compatibility

Backwards compatibility is important due to the vast amount of CAD-data which already has been accumulated and is currently being accumulated by facility management organisations. If one considers that the value of such data is comparable to the cost of re-creating that information by having a CAD-operator make the drawings anew from paper drawings, one gets a perspective on the value of having the data in a well-structured form. If the international standard is such that it is possible, using conversion tables, to translate the internal layering of most earlier CAD-applications to a structure compatible with ISO 13567, this would considerably increase the usability and value of the information. This conclusion is still a working hypotheses, and would need to be substantiated by testing on a large scale.

6.3 Forward compatibility

Building product modelling has during the last few years become a popular research subject (see for instance [Christiansson and Karlsson 1990]), and seems in the long run to offer the ideal integration platform for sharing information about buildings. Much of this activity has during the last few years been canalised to the STEP building construction committee, which has as its aim to provide a suite of interrelated standards based on the core model - aspect model architecture [ISO 1995]. In addition, there has been a rapid increase in the interest for product modelling among end users and commercial vendors, where the catalyst has been the recently-founded Industry Alliance for Interoperability. This non-profit association, with its strong ties to the leading CAD-vendor on the market, has as its aim to provide product model solutions (so-called Industry Foundation Classes) for the exchange of building data with a more rapid time-table than the STEP project [http://www.interoperability.com/].

A question which thus will be of importance is how to convert CAD-layered data to objects in a product model. In order to make this possible, the information structures used in layered CAD-models need to be defined using the same conceptual techniques that are used in product modelling (i.e., in a language such as EXPRESS [Schenck and Wilson 1994]). The STEP standard already includes the notion of layers, but only as a monolithic attribute for drawing primitives, where the attribute's internal structure hasn't been broken down further. For conversions to become possible, the different fields in ISO 13567 need to be modelled as object classes in their own right, and related to corresponding classes (responsible agent, construction activity, etc.) in such emerging models as the STEP building construction core model [ISO 1995] or the IFC core model [IAI 1996a,b,c] (for an early attempt at such a model see [Luiten et al. 1993]). Recent attempts in some building product modelling efforts, where generic building element object classes are classified using existing building element tables, could indicate a way out [Svensson 1991], [Tarandi 1993].

All in all, interesting new challenges will thus be posed by the parallel use of several different techniques in the same project [Turk et al 1994]. Parts of the overall building description data used in a project could be in layered CAD-models, parts modelled according to STEP application protocols or Industry Foundation Classes and some parts could even be in the form of traditional detailed drawings or written specification managed by document management systems. Given that the information describing buildings is relevant for periods as long as 50 years, which is far beyond the life-span of currently used CAD-software (not to mention hardware), it is a real challenge for both researchers and practitioners to design information management techniques that can cope with such hybrid situations [Björk 1994].

6.4 Extending the view to the information life-cycle

CAD use in the construction sector has been dominated by use during the design phase. Thus, the main users of the information produced have been design professional and builders. In the total life-cycle of buildings other demands for information structuring are evident. During the early phases of a construction project design consequences and alternatives have to be visualized to clients, users and authorities. After the design phase, construction work has to be managed, including the planning of activities and costs, which are to a large extent connected to the objects represented in CAD files. Eventually, during the many years of use, information should be available and presented in a suitable format to the people who use, maintain, repair and refurbish the building. At present there is limited experience of this extended use, as CAD until recently has been used almost exclusively in the design phase. A rising interest for structured information, among clients, contractors, facility managers and other participants in the process, opens the field for studies of how information can be structured and managed in the long perspective.

6.5 After the fact and anticipatory standards

Within the IT domain, standards emerge in two major ways [OECD 1991]. Firstly, after a technology has already developed, either through formal standardisation procedures or due to the choices of end users in the marketplace (a good example is the MS-DOS operating system for PC's). Secondly, in the form of anticipatory standards where standardisation bodies try to predict future needs by a number of years, before the marketplace has become dominated by vested interests in the form of installed bases of soft- and hardware. The standard for product model data, STEP, provides a very good illustration of such an anticipatory standard.

Using this categorisation, the ISO layering standard clearly falls in the first category. Those defining the standard have had to cope with typical problems caused by the vested interests of different countries and CAD user groups who have defined their own standards earlier. The solution to many such problems seems to be the definition of functional framework standards, which leave a certain degree of flexibility for actual applications of the standards.

6.6 Making best practice common practice

A superficial reading of conference proceedings from the last years indicates that the empirical study of how current commercial CAD software is used in building design and construction management is almost non-existent. Based on our knowledge of how many of the leading design firms in the Scandinavian countries use CAD, we would claim that "best practice" use of commercial CAD-systems is much more model-oriented than many researchers seem to think.

Hopefully this new standard would contribute to make such best practice "common practice". At the same time it is hoped that the standard would facilitate the use of layered CAD-data as input information for the more advanced product model based systems of the future. The possibilities for integration with document management systems are also important since many of the information categories dealt with in layering also occur in the reference information that document management systems use for document search and retrieval.

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