Application of IFC in Sweden – phase 2
Final report

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The Swedish Building Centre

Anders Ekholm, Lars Häggström, Väino Tarandi, Olle Thåström
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Cover page:

The picture can be seen as a symbol of the step by step development of IFC and applications based on IFC that is going on and eventually will fit into the comprehensive product model that we see in the future.
This is the Swedish Building Centre

The Swedish Building Centre is the information company of the construction industry. The Centre draws up, disseminates and classifies information within the construction sector.

The Swedish Building Centre collaborates with many Swedish and foreign companies, authorities and institutions within the areas of research, standardization and implementation.

The Centre endeavours to bring about rational and appropriate construction by carrying out research and providing information services and information products geared to the needs of the users.

The Swedish Building Centre is a limited company. Its shares are owned by about forty of the national organisations in the construction industry. These represent clients, consultants, contractors, construction workers, building products manufacturers, etc.

The Centre was founded in 1934 and began its work with a small building products exhibition in premises at Kungsgatan in Stockholm. Since then its work and scope has progressively developed. The activities of the Centre now cover the whole country and comprise:

- exhibition of building and building services products
- the Building Products Catalogue and the Building Products Register
- publishing, specialized in the construction field
- development of AMA (General Material and Workmanship Specifications)
- literature and information service
- training
- information systematics, for instance document co-ordination and responsibility for the development and administration of the BSAB system.

This is the Swedish IAI (SIAI)

A Nordic IAI Chapter was founded in 1996 and in 1995 a Swedish group was established to follow up the development of IAI and IFC. The board members represent different parties within the AEC/FM-industry.

One important goal for SIAI is to enable a Swedish influence on the international development.

To influence the IFC development is important, as the IFC-solutions will interact with already well-established Swedish de facto standards such as AMA, BSAB, EDI, etc. The long experience in this line of work can give an essential contribution to the work within IAI.
Summary

The overall purpose of this project has been to study the IFC specification and to examine it according to the possibilities of implementing the Swedish BSAB-system within the IFC framework. The work has been carried out partly by means of theoretical analyses, partly by using a prototype program that is capable of visualising IFC files.

The result shows that it seems possible to integrate IFC and BSAB in information exchange, but there are a lot of problems that have to be solved before programs can be brought into market. We have encountered many imperfections in IFC. The major shortcoming of IFC is however that no concern has been taken to the framework standard for construction classification, ISO 12006-2. Since BSAB 96 is based on ISO 12006-2 this shortcoming is also relevant for BSAB 96. Our suggestions for solving the encountered problems include an increased participation in the work within IAI and an increased effort in Sweden to start a number of prototypes and pilot studies with delimited goals to cover important use cases.

This report is a translation of some major parts of the complete Swedish final report which has been published by the Swedish Building Centre as Arbetsrapport 15, 2000-06-30. Those parts, which the intended readers of this report are supposed to be familiar with, are not translated.

**Keywords:** IFC, IAI, BSAB 96, classification, ISO, product model, construction process, communication, co-operation
1. Introduction

Background

From a Swedish perspective all developments within the multinational computer application industry is vital because of the widespread use of their products in AEC/FM. One important question is the impact on the methods of work. Another is the influence from the way the application is handling the information structure. The latter can principally facilitate the building of extensions and additions and even competing products. On the other hand – if the application doesn't structure the information in our way – it may raise problems getting an efficient use of the application.

This project aims at exploring how the IFC-model and the BSAB-model can interact. In a second phase this will be relevant also for other models that are under development. For that purpose the project starts with extensive studies to get a thorough understanding of the IFC-model.

The BSAB-system [1] has a long tradition in Sweden and the third generation, BSAB 96, was first published in 1994 (however with preliminary tables). BSAB 96 is based on a global view on the information needed and produced during the whole lifecycle of a construction entity. This approach has never before been expressed to such extent in that perspective and never before been based on such elaborated theories. It has of course also never been tried in practice in a computer environment before. Therefore we don't actually know if this idea with a global view of the whole lifecycle is feasible to apply in a computer program.

This project is investigating whether IFC can contribute in a positive way to this approach.

A vital fact is that BSAB 96 is wholly compliant with the framework standard for construction industry classification systems, the ISO 12006-2 [2]. This means that comparisons between BSAB 96 and IFC are equal to comparisons between ISO 12006-2 and IFC. In this report we use the same terminology as in ISO 12006-2.

This means that the results of this project are interesting also from an international perspective.

IFC will have a major impact on the way computer systems can be made and how they can be used. The construction and facilities management industry will have to face also a lot of other influences and therefore the results of this project must be judged in this context.

This report is relating to prominent commercial and other circumstances that are influencing the possibilities to carry out such great changes that will be needed to achieve the ultimate goal – an unbroken access to (chain of) information throughout the lifecycle of a construction entity.
IT Construction and Real Estate 2002

IT Construction and Real Estate 2002 is a national R&D programme for Information Technology in construction and real estate management and represents a continuation of the recently completed IT CONSTRUCTION programme. It started in early 1998.

IT Construction and Real Estate 2002 formulates a national IT strategy and has as its vision and aim an integrated, model-oriented and digitalised information and production process: planning-construction-real estate business.

The goal is to provide a common IT platform for Swedish construction and real estate companies which will make it possible for the companies to increase the benefit to the customer through improved market communication, greater efficiency, higher quality and lower costs.

This will be achieved by using IT to help change construction and management processes through the introduction of new forms of work and new technology.

Particular attention will be paid to the management phase and the existing stock of buildings and facilities.

The programme requires active co-operation between all the parties in the construction and real estate sector if it is to succeed.

The programme will be carried out in co-operation between the companies and the universities and colleges. The companies will select projects based on their particular orientation and needs, and their own research students will be responsible for carrying out the projects at a university, college or research institute. Co-operation will also take place with the school for researchers planned within the Competitive Building R&D programme. This involves a relatively limited effort on the part of the companies, but a major return in terms of the development of the expertise and know-how of their staff and new technology. [3]
2. **This project**

This project "Application of IFC in Sweden" has been split into three phases. This report covers phase two and a selected summary of phase one.

Phase three is planned to be substantially greater (6 -7 MSEK) and will start in the autumn of 2000 and end when the development program IT Construction and Real Estate 2002 ends in the end of 2002.

**Tasks and goals**

Already in the first phase the emphazies of the project were focused on:

- take part in, get information from and influence the development of IFC within IAI
- make good relations with internationally leading application developers
- get a good knowledge of IFC and of related or similar initiatives
- try how IFC and BSAB 96 can work together in some pilot projects
- inform and educate the Swedish construction and facilities management sector about related systematics and applications

The last two will be carried out in phase 3 and the other have already been reported in Phase 1.

In phase 2 the overall goal was to try how IFC could carry information structured with BSAB 96 and to make a more comprehensive study between IFC and ISO 12006-2. The cases studied were specifications and cost estimates.

**Realization**

The work carried out in phase 2 has basically been done within the following areas:

- A prototype for visualising and exploring the product model based on data from a demo-building common for projects within the programme (IT Construction and Real Estate 2002). Responsible: Väino Tarandi.
- Theoretical analysis and a more thorough comparison between IFC and ISO 12006-2. Responsible: Anders Ekholm.
- Conducting speeches on seminars arranged by the program and by others.
- Co-operation with other groups within the program and contacts with persons and groups within e.g. IAI and ISO.
- A final report for phase 2.

The results are mainly based on the latest version of IFC i.e. IFC 2.0. During the end of the project however also an incomplete beta version of IFC 2.x has been studied. Therefore only partial comparisons have been possible for the latter but most changes were considered to be good.
**Co-operation with other projects**

To ensure a substantial and natural flow of information and knowledge between projects in the program they have been populated with a kernel of key persons being active in several projects.

The project participants have at several occasions informed both other projects and end users in big companies about the project an IFC.

**Project organization**

The organisation and population of the project has been the same as in phase 1:

Project leader has been Olle Thåström, AB svensk Byggtjänst. Responsible investigator for systematics and classification has been Anders Ekholm, PhD at CAAD, LTH (Lund Technical University), and the responsible for participation in IFC and expert in STEP has been PhD Väino Tarandi, Eurostep. Lars Häggström, MSc CEng Manager Systematics, AB Svensk Byggtjänst has assisted as expert in BSAB.

The board of SIAI (Swedish IAI) has acted as the steering committee however not formally but as actively participating in the project.

**Results**

The results of the project are published in this report. It has been finalised by the project leader who also has written the common parts and the overall description of IFC. Each responsible investigator has written their part of the report i.e. chapter 4, Anders Ekholm and chapter 5, Väino Tarandi. Therefore it is natural that some issues are somewhat overlapping and that you can find differences in ways of writing and in views.

The analysis of the theoretical basis of IFC is made from a strictly scientifically viewpoint within the systems theory. Parts of the material have been discussed with representatives from IAI and an interest and understanding of our criticism has been noted.

This report is intended to be used also in other forum than IAI and has been written accordingly.

Our common general conclusion is that it is possible to use IFC together with BSAB for the transfer of information between computer programs. There are some problems that needs to be solved in order to achieve this but if focusing on limited areas where the need of interchange is big and the use is evident there are some possibilities to succeed.

Prototypes and pilot implementations have to be done within limited key areas in order to approach practical use. Swedish software houses must be engaged in the prototypes and in the pilots and the theoretical studies must have been done prior to this.
Relevant experiences will be submitted to IAI to enhance the development of IFC. To support this the program is expressing a strong national commitment to IFC and a willingness to support an extensive participation in IAI in leading technical roles.

The results from the work has to be communicated both internationally and nationally in order to get acceptance from the end users and make them request the emerging products.

Next phase

One of the overall goals of the program is to improve the communication between the actors in the AEC/FM industry. This can be achieved if all information concerning a construction entity can be shared by all actors. One vision is to have a common product model (database) were all information is stored and retrieved.

This way of working puts big requirements on the administration of the database. In the complex context of the product model, access rights, handling of versions and so on must be dealt with in a secure way as well as the communication with a number of different software for input and retrieval.

The project has come to the conclusion that this cannot be done in one huge lap but must be achieved by many steps of small changes in processes and methods based on current practice. It is not realistic to believe in a fast and revolutionary change of today's situation.

The Construction Industry is often accused for tardiness and unwillingness to changes, especially concerning IT. It is likely that this is true but the reason might be rational and due to lack of incentive. At least up to now often "someone else" has collected the economic gain of a rationalisation or productivity improvement. This all has its roots in the basic structure of the branch and the processes.

In the following presentation a couple of different viewpoints are expressed that ought to be tried in order to obtain enhanced or new software. The idea is that these easily must get accepted by the end users and give profitable improvements.
3. IFC

In this chapter only those parts that are considered to be of special interest outside of Sweden are translated into English. Therefore the parts explaining IFC, its different versions and the idea of interoperability are omitted.

**Overview**

There is a big need to be realistic about IFC. It isn't something "magical". It is a system built by many people from many countries during a relatively short period of time. This fact is strongly reflected in the model; it is very large and not fully consistent and has a variety of details in different parts and different solutions to similar problems within different areas. The degree of involvement by "IT-people" is very high and therefore it is not surprising to find that the framework standard for classification in the AEC industry (ISO 12006-2) hasn't been taken into account yet. The model is hard to get an overview of and it takes a lot of time and effort to understand it. The main criticism that can be addressed to IFC is the prominent lack of an expressed basic philosophy and pedagogical descriptions related to experienced needs.

Regardless of these shortcomings the main impression is that IFC is an effort in the right direction and that it is steadily improving. Whether or not it will be named IFC or something else in the future is however hard to tell.

**Evolution of software, IFC and classification**

The evolution of software has resulted in more and more complex and useful functions that are closer and closer to the complex real world. Therefore it has proved necessary to base the programs on models i.e. simplified descriptions of the world. The technique used is called object orientation and has its origin in programming techniques where there is a need to handle programming units with common properties in a similar way. The very basic roots are however to be found in the systems science on which the framework standard for construction classification, ISO 12006-2, and the third generation of BSAB are based.

IFC has historically emanated from CAD systems and classification from specifications, cost estimates and production planning. The ISO 12006-2 and BSAB 96 are however also designed to handle CAD information. The elements table is recommended to be used in the Swedish application of the ISO standard 13567 for organization and naming of layers for CAD.

**Area of application**

The overall goal of IFC is software interoperability in the AEC/FM domain.

This means that IFC must be handled by virtually all software carrying information about a construction entity and related processes during the whole lifecycle. This is a very ambitious goal and a lot of power is needed to achieve this in practice. Even if
this goal will be obtained only for some major parts it will be of an outmost impor-
tance to the industry.

**Problem areas**

IFC and ISO 12006-2 are defining the objects differently and have different objects even if some are very similar. This means that an interpretation of IFC has to be done when using classifications based on ISO 12006-2 (e.g. BSAB 96). In software normally only selected parts of IFC are used and this also demands an interpretation of IFC. These interpretations have to be defined very accurately in order to get interoperability.

One question that has to be answered is whether or not it is possible to use the classes already defined in IFC instead of national classification systems. We have found that the IFC classes are very few, they are lacking necessary definitions e.g. for how to be measured and IFC doesn't seem to have the intention to do this work. The BSAB 96 system has around 10 000 classes which gives an idea of the number of classes needed.

IFC is currently lacking all classes that are not represented in CAD however many of those are needed in e.g. cost estimate systems.

There is a lack of definition of how different software are going to internally select IFC classes for different objects and therefore its not possible to tell how this can be combined with e.g. the BSAB system.

So far IFC is focused on Architecture. Project management (CM), facilities management (FM) and HVAC have not been really included yet. This is a very strong limitation for an overall interoperability since the main problem is to make relevant information from earlier stages available to the FM processes.

IFC is very flexible which creates problems if different programs write files in different ways and have different perceptions of how to interpret files. We have encountered some examples showing this. IFC has started introducing the concept of conformance classes to cope with this.

The representation of drawing oriented information must be done according to national standards. This has to be solved in the software but IFC has to take this into account.

IFC has the ability to express property sets. In contractual documents the specifications are national. They are carrying a lot of properties implicit in the classification and explicit in the text and in the referred standards. This means that the use and/or definition of property sets cannot be fixed in IFC but has to be adapted to the national systems.

If there is a need and a demand for property sets to be included in IFC, rules and recommendations for this have to be defined.
In the same way information about construction products and other products has to be included. This is the clients/owners responsibility and will have an increased importance in the future.

One of the difficulties in understanding IFC lies in the objectified relations. The objects are not directly related – between them there is this relational object. This is however very much improving the flexibility.

**What is a product model**

A common scope definition is "all information in the lifecycle of a construction entity". This is however not realistic. A lot of information is only vaguely connected to the construction entity and many processes are creating new information based on the existing and some of this information is never used by other processes.

A limitation to common information could be reasonable but this also raises problems. This has to be clarified.

Another thing is that product models must not be mixed up with project databases.

**Implementation of IFC**

To implement IFC it has to be able to express the real needs of communicating information. Due to differences in legislation, culture, climate and perceptions of the built environment in different countries IFC has to provide for national adaptations. IFC will play a very important role as a common framework, which will be a good basis for the harmonisation in Europe.

**Needs and uses**

Most people think it is sufficient if IFC will eliminate problems for information transfer between CAD systems and a secure archive for information about the construction entity.

This is an unnecessary limitation. There is much more power in the concept of the product model.

It is not reasonable to believe that CAD systems will specify a construction entity by itself. As a matter of fact a lot of other software and information bases are needed. If all this software can use the same product model the software will be able to be improved radically and there will also be niches for specialised programs for small groups of users. A feature of special interest will be the ability to compare information created by different software and/or actor. This has a high economic potential because a lot of problems due to lack of consistency could then be eliminated.

This check could be done concurrently e.g. when drawing and specifying. The prototype that has been developed in this project gives a hint of how this way of looking at the product model could be done.
Interoperability

In the following a very simplified model of interoperability is presented and discussed.

The phenomena of a construction entity represented by a CAD program are mainly elements and designed elements. More accurately plans, sections and facades are geometrical views of parts of the construction entity. By assigning a type code (in Sweden called "littera") to parts with the same function and composition they can be treated as a unit. Normally these parts are classified as project specific designed elements. In most software no link on the level of occurrence (individual things) are normally established to other software. In the CAD model also work results are presented but often only textually. All elements and designed elements and most work results are not in the CAD model.

To establish interoperability between the CAD model and other information models e.g. for specification and cost analysis is fairly easy if looking at a static situation when the CAD model is finalised. However this is of course not the normal situation and there is needs to track which changes in one model that have consequences for another model.

In IFC the CAD view is rather well established but also the other views e.g. for specification, cost analysis and production planning have to be specified.

One way communication

The method that has been tried with IFC so far is what could be called a one way communication. IFC files have been exported from a CAD system and imported in other systems but the information added by those systems have not been transferred back to the CAD model. This seems to be a reasonable method to be used for the pilots to reduce the complexity and obtain more controlled tests.

Studies of IFC in other countries

A number of demonstrations have been carried out by IAI. Transfer of IFC files between different software has been demonstrated. In general these demonstrations have been very important and have dramatically increased the interest for IFC. However from a technical viewpoint the value is limited because the material have been prepared, only parts that works have been shown and principal and general issues have not been on the agenda.

As far as we know no critical review of the IFC framework has been presented and it hasn't been studied in relation to the ISO 12006-2 framework or established national classifications.

This gap is intended to be filled in by this project. When doing this a lot of adjacent initiatives will be studied e.g. BLIS (Building Lifecycle Interoperable Software) [4].
4. Analysis of IFC

Classification

In this chapter the relation between IFC and established construction classification, the international framework standard ISO 12006-2 (ISO 1997) and the Swedish BSAB 96 system (Svensk Byggtjänst 1998) is described.

Construction classification has been developed to facilitate information exchange in the construction sector, e.g. for cost estimates and specifications as basis for tendering, but also for structuring information in libraries, CAD and databases.

Construction classification is not identical but varies among countries and regions, depending on prioritised views, techniques and work organisation. During the period after the Second World War, the Swedish SfB system gained wide dissemination in Europe, and is still used in developed form in many places. This has been significant for the establishment of the common view on construction classification that after all exists and that has come to expression in ISO 12006-2.

To facilitate the development of an international market, standards for business messages in the construction sector, EDIFACT, and for classification of construction products, have also been developed. The latter has recently been released in its second version, EPIC 2.0 [5].

ISO 12006-2 an international standard for construction classification

In the international standardisation organisation ISO, a basic standard for construction classification has recently been defined (ISO 1997). The work has been carried out by ISO/TC (Technical Committee) 59 “Building Construction”, SC (Sub-Committee) 13 “Organisation of information about construction works”. Swedish representatives have had a significant role in the work.

The classes in ISO 12006-2 are intended to support the complete life cycle of the building, including design, manufacturing and use. The standard does not include any classification tables but recommends suitable ones to be defined by national and regional organisations. The purpose of the standard is to lay a foundation for a common international view on classification in the construction sector to support information exchange, e.g. in CAD, specification, and cost estimates.

In ISO 12006-2 a diagram is shown where the different classes are related to each other. See Figure 1. The ISO standard is based on a process model where one can identify resources, processes and results. All of these are “Construction objects” with “Property/Characteristics”.

The construction objects are defined in the standard by descriptive definitions that state the immediate super class together with class separating characteristics. An example is the definition of “Element”: “Construction entity part which, in itself or in combination with other such parts, fulfils a predominating function of the construction entity”.
The diagram in the ISO standard presents sub and super class relations as well as relations like part of, and result of. Other relations in the ISO diagram are not defined in the standard and shall be viewed as guidance for the understanding. Relations like “position” or “connected to” between construction objects are not defined in construction classification.

![Diagram of construction classification](image)

**Figure 1. Relations between results, processes and resources in ISO 12006-2**

**Fundamental principles in classification**

Fundamental for construction classification according to ISO 12006-2 is to separate between different views on a concrete object. These views reflect the need for information in various processes. For example, the classes Element and Work result are alternative ways of describing the physical parts of a building. The class Element is defined by function in the completed building, while Work result represents the construction result made up from worked and mounted Construction products.

A cost estimate for the building can be carried out either based on Elements or on Work results.

The class Construction product is defined by characteristics as resource to be built into the building, i.e. possible function, construction and material characteristics.

Another example of division into views, directed towards function and composition respectively, is the class Construction entity, which is determined on the one hand by
function for the user, e.g. school building, and on the other hand by its construction type, as building, bridge or tunnel.

The overall principle in design implies that starting with functional requirements, a suitable technical solution is determined. This division of views in the classification systems aims at supporting a successive definition of characteristics.

The diagram in Figure 1 reflects the common approach to processes and results, on wholes and parts, and on views of interest, that have been developed in the ISO group. The approach recurs in the national, regional or company specific applications of the standard. The purpose of following the standard is to create conditions for information exchange. Even if the application of the tables may vary, several of the classes will still be the same through the common standard.

**ISO 12006-2 in EXPRESS-G**

Figure 2 presents the diagram from Figure 1 in EXPRESS-G notation, used in the context of product model representation. EXPRESS-G is a graphical counterpart of the formal EXPRESS language. EXPRESS-G does not have the same ability to express relations among classes as EXPRESS but is one way of illustrating these relations (Schenck and Wilson 1994) [6].

Classes are shown with boxes, the fat lines with the circle as a pointer shows the specialisation of a class. The number “1” means that an object may only belong to one of the specialised classes, while “andor” means that an object can be classified in more than one way. Thin lines mark relations, their kind are written in text along the line, the numbers within square brackets indicate cardinality, i.e. the amount of relations objects may have. For example [1:?] means “one to many”.

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Application of IFC in Sweden
The BSAB system

The Swedish BSAB system follows the principles from the ISO standard. The corresponding diagram as the one for ISO 12006-2 is shown in EXPRESS-G in Figure 3.
The Industry Foundation Classes, IFC, aims to become an industry standard in the construction and real estate management sector for transfer of product model data among information systems. The standard is developed through the Industry Alliance for Interoperability, IAI, whose members are software developers or users (IAI 1999). Experts with specific knowledge of the IFC standard do the actual development work.

The purpose of IFC is to establish a common way of describing data for different applications, both with regard to conceptual content, terminology and exchange format. The purpose is to achieve interoperability, i.e. information transfer without information losses and without the need for intermediary human interpretation.

In product model based applications, the designed object, e.g. a building or its parts, is represented by a data object. Information like ID, name, geometry, relations and other attributes may be attached to the object. The development of IFC is intended to encompass every object of interest to the construction and real estate management sectors.
**Objects and levels in IFC**

In an information system a distinction is made between the language in which data are expressed, the so-called data definition language, and that which is expressed, the data model. IFC uses EXPRESS as data definition language. The basic data units in EXPRESS are entities, attributes and relations (Schenck and Wilson 1992:26). These units in EXPRESS can be regarded as equivalents of nouns, verbs and adjectives of natural languages.

IFC 2.0 takes as its starting point these units of EXPRESS to define the so-called IFC Meta Model, consisting of IfcObject, IfcRelationship, and IfcPropertyDefinition. These fundamental objects are successively specialised into classes like IfcProduct, IfcProcess, and IfcControl, and different relations like IfcRelContains and IfcRelGroups. In this level, basic functions are defined, e.g. position, process stage, the part-whole relation, couplings and groupings of objects., These classes together constitute the IFC Core Model.

The next level is called the Core Extensions layer, which consists of specialisations of the Core classes. As an example, IfcProductExtension defines basic objects for the construction and real estate management sectors like IfcElement, IfcSpace, and IfcBuilding.

The next lower level is called the Interoperability Layer, and holds classes common to different actors and disciplines in the construction and real estate management sectors. Here one may find, for example, IfcWall, IfcBeam, and IfcElectricalAppliance. In the level below this is found specialised extensions for separate disciplines.

**Relations to classes in ISO 12006-2 respectively BSAB 96**

A comparison between classes in IFC with classes in ISO 12006-2 and in BSAB 96 show great similarities. Classes in the Core and Core Extensions are found in ISO 12006-2, and classes in the Interoperability layer, as well as its further specialisations, are found in BSAB 96. Figure 4 illustrates the class hierarchy of IFC 1.5, as well as the position of the corresponding classes of the ISO-standard and BSAB 96. Presently, IFC 1.5 has been superseded by IFC 2.0, but the principle for the comparison is still valid.

A fundamental idea of IFC is that an object, for example in a CAD-system, may be equipped with attributes so that it may play different roles or be part of different systems (IAI 1997:2-15). The object shall also be possible to classify according to different classification systems. In IFC 1.5 classification could be attached to IfcResource, in IFC 2.0 this was extended to also include IfcProject, IfcProduct, and IfcProcess. In IFC 2.x, which is planned to be released during fall 2000, it will be possible to attach classification to every IfcObject.

Definition of the class that an object belongs to is in the proposal for IFC 2.x done through IfcRelClassifies that relates IfcObject to either an internal or an external classification table of classes (IFC 2.x 2000).

During classifying it would be logical to strive for a correlation between the IFC object attributes, and the attributes that are in the definitions of the classes of the exter-
nal classification system. For example, classes in the IFC Interoperability Layer in several cases correspond to Elements in BSAB 96, defined by functional attributes. If an IFC object has only functional attributes, it should not be classified as a Work result, since this is not defined with regard to function but construction.

**IFC and design**

The structure of the IFC framework and the principles for its use, are based on the conditions of today’s CAD systems for building design. In such a CAD system the product definition starts from a number of CAD tools for Wall, Floor, Ceiling, Stair etc. When starting the user chooses one of the tools, e.g. Wall, and starts to define characteristics like geometry, material and screen presentation. In computer technical terms an individual wall object is created as an “instance” of the generic wall that is programmed in the system. The continued product definition proceeds in the same manner with other objects until a complete representation of the building is produced. Conceptually, one can say that the instances are specialisations of the more generic program classes. This procedure for product design could be called the “CAD-paradigm”.

An alternative to the established procedure within CAD could be to give the user possibilities to initially define an object without other characteristics than identity, project and creator, approximately similar to the meta data every Word document may have. After this the user should be able to determine if the object shall be a wall, and thus get access to the characteristics that the wall tool gives. Other characteristics, which not necessarily belong to a wall object, e.g. “red brick”, a material char-
acteristic, should be possible to add using a tool for construction design. This way of working would much more resemble the procedures of established drafting based practice. It would also give the user the advantage that some characteristics can be deleted from the object without the need to “throw” away the object itself. One example could be when the user wants the object to change from a wall to a row of columns, certain geometry and relations to other parts of the building could then be kept, as the wall attributes were changed to column attributes.

The established construction classification is based on and supports this latter kind of “flexible” product design, while IFC is built completely around the “CAD paradigm”. Established practice is much better adapted to flexible product design than the CAD paradigm. It is reasonable to assume that the transition towards model based CAD will mean that the CAD paradigm is abandoned in favour of flexible product design. This puts requirements on IFC to be fundamentally restructured, e.g. it must be possible to instantiate a neutral object with only ID and other meta data. Exactly which changes that are necessary can not be judged in this report, but has to be the subject of a separate analysis.

It is an official purpose of IFC to be an industry standard in the construction and FM sector for exchange of product model data between computer systems. To support this, IFC has to be adapted to a flexible product design, and support exchange of information structured according to ISO 12006-2 and also various national and regional systems based on this standard.

**ISO classes in IFC**

One main purpose behind IFC is to be used for the needs of the construction and real estate management sectors. ISO 12006-2 is one expression for these needs and it is therefore necessary to analyse in which way classes and relations in the ISO standard can be expressed in IFC.

The structure of the IFC-schema is different from that of the ISO-schema, therefore it is not immediately obvious how an ISO-class can be “mapped” onto an IFC class. In Figure 5 parts of IfcKernel and IfcProductExtension have been combined to facilitate a comparison.

IfcElement is a super class of IfcBuildingElement and IfcOpeningElement. The latter class refers to openings, voids, that can be filled by the latter. IfcOpeningElement originate from the needs in CAD and is not found within building classification.

The ISO classes Element, Designed Element and Work Result and their correspondents in the BSAB system ”Byggdel, Byggdelstyp and Produktionsresultat” constitute different views on the physical parts of the construction entity; they correspond to different information needs depending on phase and actor. Work result does not exist in IFC but could for example be represented by IfcElement with the addition of reference to a work result class in the BSAB 96 system. Plausibly, the class IfcConstructionZoneAggregationProduct is intended to support this need but that has to be made clear in the IFC-specifications.
The IfcBuildingElement can be viewed in two ways. On the one hand it can correspond to ISO’s Construction Entity Part; meaning that it is not defined more than as a part of the Construction entity. The idea in IFC is that IfcBuildingElement can have characteristics added and be classified according to these, i.e., if it’s compositional characteristics are defined it can be classified as Work result. On the other hand, the sub classes to IfcBuildingElement, e.g., IfcWall and IfcFloor, are functionally defined which makes it correspond Element/Byggdelar in ISO/BSAB 96.

Figure 5. Parts of IFC in EXPRESS-G

IfcElement is intended to represent construction products, i.e., ISO’s Construction Product. It is not clear if IfcBuildingElement has to be a part of the construction entity or if it also can represent products/articles.

IFC 2.0 uses the relation IfcRelContains. The objects that an IfcBuildingElement may be part of are IfcSpace, IfcSite, IfcBuilding, and IfcBuildingStorey. This is stated in WR 42 for IfcElement. WR stands for “where rule” and is a restriction expressed as a rule for which attributes an individual may have. See the documentation of IFC 2.0.

A space in IFC is not directly related to a Construction entity but first to IfcBuildingStorey. In WR 53 for IfcSpace is stated that “the sub classes of IfcProduct, which may contain spaces, are: IfcSite and IfcBuildingStorey”.

IfcBuildingStorey is related to the building through IfcRelContains. See WR 42 in the definition of IfcBuildingStorey.
A hospital, an airport, or a road between two places, consists of several construction entities which together enable an enterprise to be prosecuted. This group of construction entities is called Construction complex in the ISO standard. The concept in IFC closest to this is called Building complex, and is created through the relation IfcRelGroups between IfcBuilding and IfcGroup. The latter has the text attribute GroupPurpose, which in this case is called “BuildingComplex”.

**Conclusions**

IFC can from the classification point of view be described as a framework of classes to be used for information exchange between computer systems. For the exchange to be complete, a correspondence between the classes of the sending and receiving systems are needed. The technical file format is here of secondary importance, primary is the correspondence of class definitions and attribute value domains. Information exchange between systems isnever better than the correspondence between these, the common subset. In order not to deteriorate the exchange it is required that IFC can depict both systems correctly. This puts great, not to say impossible requirements on IFC.

One solution could be that the national and regional systems are abandoned in favour of IFC. This requires extensive international work and can not be expected within foreseeable future. Only when established national and regional standards are missing, can IFC be an alternative. Primarily, this is the case regarding standardised geometrical representations of objects in different classes, e.g. in CAD systems, and regarding standardisation of relations between objects. It is in these areas that are not covered by established construction classification where IFC can be important.

One weakness in IFC is the lack of explicit models of products and processes in different abstraction levels, which would ease the understanding of how to apply the system. Only the object definitions are now reflecting the underlying concepts. This may result in the experience that the relations between the classes in the framework are somewhat unclear. This problem has also been experienced by others, e.g. Jiri Hietanen has developed the so called “concept block approach”, as a means to create overview and structure in the IFC model (Hietanen 2000).

The lack of stringent and coherent definitions of concepts, and a simple and comprehensible terminology, is a problem within the IFC standard. For example, the relation IfcRelContains, which is mentioned in the section about ISO classes in IFC above, is used to represent the part-whole relation. The term “contains” is unfortunate since a whole cannot exist without its parts, e.g. there is no building without building parts. On the other hand a container may well exist without contents.

To increase the overview and to create clarity and coherence in the development of the framework within IFC, it is necessary that explicit models are developed in at least two levels, the ontological, corresponding to the Core, and that which concerns products and processes in construction, corresponding to Core Extensions. A model for the Core shall concern the most generic properties of products and processes, like the ontological model for BSAB 96 (Svensk Byggtjänst 1998). An explicit model for Core Extensions should be based on the model for ISO 12006-2.
IFC has not solved the issue of managing Work results. Sub classes of IfcBuildingElement, e.g. IfcWall and IfcFloor, correspond to functionally defined ISO Elements. The easiest way would be to complete IFC by defining IfcBuildingElement as equivalent to ISO Element and to create another sub class to IfcElement, e.g. IfcWorkResult corresponding to ISO Work result. Also Construction product in ISO should be given a class of its own, independent of the construction entity.

An important conclusion of this analysis of the relation between IFC and established construction classification is that IFC ought to apply the international standard (DIS) for construction classification ISO 12006-2.

As mentioned in the section “IFC and design” above, IFC is based on the so-called CAD paradigm, and does not give support to flexible product design. It is an outspoken aim of IFC to become an industry standard for the exchange of product model data between information systems in the construction and real estate management sectors. In order to achieve this, IFC has to be adapted to flexible product design and support exchange of information structured according to ISO 12006-2 and different national and regional systems based on this standard.
5. Prototype work

Background

Eurostep has within the project frames developed a prototype for a testing tool, which can read and write IFC files. As an extension, also XML files can be read and written for some selected information constructs.

The starting point for the prototype work was to illustrate that IFC, revision 2.0, can manage the information for a construction entity and its parts, that is exchanged between designers and construction companies (building elements, work results and spaces). To limit the effort, of financial reasons, it was decided to work with a limited set of building element types.

As test data a building from the BSAB Demonstrator project, designed in AutoCAD R15 with the application POINT 5 was chosen. The files were delivered in the mxf format, a Swedish extension of dxf by Cadpoint, where some object characteristics also are possible to transfer in the file. Mxf is not a standardized format.

The goal was to do exchanges at practical tests with the help of a prototype where the results could be shown using various visualization tools.

Test environment

The prototype was built in an environment based on Windows 98 from Microsoft. The various parts are illustrated in figure 6. The heart is Ifc Toolbox from Eurostep. That is a software which is automatically generated from the EXPRESS schema for IFC 2.0. The interface towards Ifc Toolbox consists of a C++ library, which can be integrated with an individual application. In the prototype a connection has been made using “mapping” to an ActiveX layer and a Visual Basic user interface. The starting point for this was the EXPRESS schema for the “Business” model, i.e. the defined subset of the Ifc 2.0 schema which supports the business process the prototype was supposed to support, see figure 7 and 8. As input data to create the product model AutoCAD files in dxf/mxf format and BSAB 96 files in XML were used. The product model can be exported and imported as Business Part21 files or IFC Part21 files, see IFC file format below. The product model in IFC Part21 format can be visualized regarding geometry and properties via the Visual Basic interface, which was provided with a simple geometry viewer.

The resulting IFC Part21 file can also be used by all software that can read IFC 2.0 files. As an example a VRML prototype, ProMoTe from VTT in Finland, was used. It converted the Part21 file into VRML format and presented it on the screen in Web tool Cosmo player from Computer Associates International, Inc., www.cai.com, see figure 10.
Figure 6. The architecture for the prototype – based on two conceptual schemata (Business and IFC 2.0 Model). The framed part defined the content of the prototype software.

Conceptual schemata

As the complete schema IFC 2.0 is large the need to use a subset of it has emerged. At the same time there is also a need for managing own specific concepts, e.g. in connection to specific software. In the “Business” schema the new classification construct from IFC 2X was used.
Figure 7. Business schema part 1. All classes have names starting with „bus“ for identification.
Figure 8. Business schema part 2. Parts like Classification are managed according to the proposal in 2X.
Result

The read dxf/mxf file from the CAD system was converted to “building objects” with related geometry and properties. Classification codes according to BSAB 96 were attached to each object. The code tables were imported to the prototype in XML format. Figure 9 illustrates an example where a wall with graphics is presented with related geometry and attributes. The left table shows the object tree, i.e. a breakdown into classes and occurrences. The right table shows the codes in the classification system, where the ones related to the current wall are highlighted in red.

From the product model various information can be selected and transformed into different formats – IFC Part21, XML etc. In figure 11 a simple “bill of quantities” is created as an XML file and shown using a matching format file, XSL file.

Figure 9. An example where a wall is shown in relation to other objects of the class. To the objects several classification codes have been attached – both for building element function and work result break down.
Figure 10. VRML model presented in Cosmo-player.
List of building elements

<table>
<thead>
<tr>
<th>BSAB</th>
<th>Name</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Unique ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.C/11</td>
<td>Betong 375</td>
<td>24375</td>
<td>375</td>
<td>6700</td>
<td>999dec35853876000001</td>
</tr>
<tr>
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<td>1124.3</td>
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<td>999dec35853904000009</td>
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<tr>
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<td>2400</td>
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<td>7491.5</td>
<td>323</td>
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<td>2400</td>
<td>999dec35853970000053</td>
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<td>2400</td>
<td>999dec35853975000057</td>
</tr>
</tbody>
</table>

Figure 11. A simple bill of quantity in XML format presented in MS Internet Explorer. Wall individuals are shown with a few simple properties.

**IFC file format**

The file format used for IFC is the same as the one used within ISO STEP, i.e. ISO 10303 – 21 [16], in short Part21 format. They are readable ASCII files with row numbers for identification.

Every line starts with the name of the object class and attributes/characteristics follow within brackets. #1725 means that the value of the attribute can be found on the line with the number 1725. Below follow two examples, one for each schema in the prototype – Business respectively IFC 2.0 standard.
**Business schema Part21 file**

```plaintext
#1714=busClassifNotation(#137,#425,#771);
#1715=busRelClassifies(#1714,#1713);
#1716=busProductDefShape('999okt83328559000061',(#1717));
#1717=busShapeRepresentation($,"",(#1724));
#1719=busCartesianPoint(37667.6,13017.1,0);
#1720=busDirection(0,-1,0);
#1721=busAxis2Placement3D(#1719,$,#1720);
#1722=busCartesianPoint(0,-48,0);
#1723=busLocalPlacement('999okt83328559000063',#1721);
#1724=busBoundingBox(#1722,5882,96,3000);
#1725=busSimpleProperty('Thickness', '96');
#1726=busPropertyset('',0,0,#1725);
#1727=busRelAssignsProperties('',0,0,#1726,(#1713),'';

**IFC Part21 file**

```plaintext
#488 = IFCCARTESIANPOINT ((39515.6, 7135.14, 0.));
#489 = IFCDIRECTION ((0., -1., 0.));
#490 = IFCAXIS2PLACEMENT3D (#488, $, #489);
#491 = IFCLOCALPLACEMENT ('99sep274265616000152', #5, $, #490);
#492 = IFCMATERIAL ('Material', $, (), ());
#493 = IFCMATERIALLAYER (#492, 0., 1.);
#494 = IFCMATERIALLAYERSET ((#493), .F.);
#495 = IFCMATERIALLAYERSETUSAGE (#494, 0., .F.);
#496 = IFCCARTESIANPOINT ((0., -48., 0.));
#497 = IFCBoundingBox (#496, 1848., 96., 3000.);
#498 = IFCSHAPEREPRESENTATION (#6, 'ReprId', 'ReprType', (#497));
#499 = IFCPRODUCTDEFINITIONSHPAEE ('99sep274265615000150', #5, $, (498));
#500 = IFCWALL ('99sep274265615000149', #5, $, (), #491, (#499), $, *);```
Within ISO STEP, work to define a XML based format is now ongoing, part 28. (http://www.nist.gov/sc4/step/parts/part028) The format will probably be used in parallel with Part 21.

**IFC and the product model**

The IFC schema defines a framework for how a product model should be structured, i.e. the characteristics, which may or must be defined for a given object class, e.g. windows. The information about a product model or its parts can be exchanged between two actors in the form of files in the ISO STEP Part 21 format. The files can be sent directly between the application programs and is then called direct exchange.

The goal is to be able to create a project database in the form of a product model where all information of common interest for the project is stored and easily accessible for all authorized.

The product model can then successively be updated, completed and modified, and always be up to date for the various actors, see figure 12. The project database can be located centrally or distributed over the network.

![Diagram of the IFC product model](image)

**Figure 12. The product model in the middle, accessible from various applications.**
Proposals for further development of the prototype

For the future development of the prototype the following is proposed:

• Show Building Elements/types – chose to show/modify related Work Results
• Manage the type concept in a practical way
• Manage complex Building Elements – e.g. Outer Wall, Bathroom ...
• Generate XML files with Building Description
• Manage rooms with connections to Building Elements/types
6. IFC in Sweden

National conditions

The interest for IFC in Sweden has so far been limited to a small group of people and companies. This group has been widened lately thanks to a number of information efforts and can now be said to contain those companies which are developing software and units in big companies which have a strategic responsibility for the IT development.

The use of IT in Sweden has been investigated [7] and shows not surprisingly that computers are the most important tools for most people. The understanding of the construction process as an information process seems to be less widely understood.

In Sweden the BSAB system was solidly rooted many decades ago and there is a healthy tradition of having contractual and other legal and official documents in a good order. For the moment there is a steadily move from BSAB 83 to BSAB 96.

In the next phase the project will establish a co-operative contact with virtually all major software available and commonly used in Sweden in the AEC/FM industry.

Processes and methods

Most technical provisions are in place to introduce an improved handling of information in the AEC/FM area but there are more obstacles to overcome. Without getting into details we have found two ways to proceed.

The first is to encourage and administrate a co-ordinated development of software to ensure that they can work together. This can partly be done in projects financed by the program.

The second way is to make clients in the AEC/FM industry demanding structured information in the contracts. This standpoint and the reasons behind it must be clearly communicated to the industry.

End users

To make the end users of software demanding new products and new ways of working a lot of information has to be communicated. This will be one of the tasks for the next phase in this project.

Experiences

In the next phase a lot of experiences from earlier projects will be taken into account e.g. NICC (Neutral Intelligent Cad Communication) [8] and Prefacto [9]. Prefacto is showing how information can be transferred between a CAD system and a system for production planning.
The timetable

Our judgement is that operative versions (in contractual contexts) of IFC and its applications will not be realised in the near future. There are a lot of problems to overcome before the vision of IFC can be within reach – if it ever will. To obtain realistic milestones, in projects that are developing IFC, they have to be divided into steps with clearly defined goals.

General conclusions

Future projects developing or implementing IFC in Sweden can be organised in different groups and we want to emphasise on the following:

Strategies, short-term and long-term goals need to be scheduled on a common level for the whole AEC/FM industry. This implies that consensus has to be reached between a lot of different actors in order to agree on i.e. which areas to focus on and in what order.

Within such a framework it will be possible to carry out projects aiming at products that will be accepted by the market. Such projects ought to include all phases in the construction and facilities management process. Software houses as well as end users have to be engaged and the results must be publicly available.

A crucial area that must be developed to a satisfactory degree is the theoretical basis for product- and process models and for classification. Also other disciplines ought to be developed i.e. terminology, design theory and methodology and development of efficient user interfaces for software.

A general remark that also is valid after the program has ended in 2002 is that Sweden has to take an active part in the development of IFC. By doing this our experiences from different projects, software and information services can be taken into account or at least known in the development or IFC and in other international contexts.
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