Object Information Packs as a base for Information Modelling in Construction

1 Introduction

1.1 The integration problem

Building is considered to be the oldest engineering discipline in history. A construction project undergoes many phases in its life cycle, starting from the feasibility and viability studies till the operation of the facility itself and its demolition. In each phase the role of one participant is considered to be the major player. Each of the disciplines involved in the construction process has a peculiar organisational culture, objectives and views of the project. For example, the architect is most probably concerned about functionality and aesthetics. The contractor is more concerned about optimising construction logistics and meeting time schedules. This more often than not leads to conflicts of interests and poor communication. In brief, the construction industry is sequential by nature; it undergoes many phases where the output of one phase is the input to the other. The life cycle of the product is longer than other engineering products. Moreover, urban and construction projects have environmental and social impacts; which have to be assessed.

As a reflection to the above-mentioned characteristics of the industry, the application of Information Technology (IT) has more often than not considered to be as isolated islands of automation. Furthermore, different disciplines in different geographical regions use different vocabulary for the same elements and have different views and classification systems. e.g. Master format in the US and NBS in the UK. This difference of views is also applicable among disciplines; an architect would have the view of a wall as a space partition, while the civil engineer would be more concerned about its structural and bearing properties. The same is applied to software applications; each has its own view to data and information. Usually the construction process ends up with a huge amount of inconsistent fragmented data, and whenever needed again, might have to be recreated from scratch.

Another cause of fragmentation is the existence of various procurement systems or topologies. This ranges from the traditional conventional systems, where the design and construction processes are separated, to the Design & Build (Turnkey Projects), where one party takes over the full responsibility. In the meantime, the trend to use private finance initiatives or BOOT (Build Own Operate Transfer) systems makes it difficult to consider the role of different parties as constants. i.e. the software applications have to be flexible enough to satisfy the needs of this wide range of procurement systems.

By investigating the role of CAD in the design process according to (Howard 1998) and (Goldberg 2002), it was found to be on two levels:
The first level enables the drafting and drawing of two-dimensional complicated geometrical shapes. i.e. a drafting tool that enables copy, paste, mirror, rotate and other functions in order to save time and effort in addition to ensuring accuracy. The second level, which is far more advanced, is the use of objects or components. Most CAD developers are currently migrating lean CAD models to the more advanced object based systems where the use of inheritance is considered to be a key characteristic that enables the desegregation of a design into its original elements or objects, (Howard,1998), (Bentley 2003). Efforts to bridge the gap between islands of automation have taken three main forms:
* Neutral file formats * APIs * Building Object Models

1.2 Neutral File Formats

Neutral formats (e.g. RTF (Rich Text Format) for the text files and DXF (Drawing Data Exchange Files) for drawings) are used by software packages to enable the import and export of different file formats across different applications. This approach to integrity is useful in many cases, however other aspects and side effects have to be taken into consideration. The bandwidth, richness and quality of information may suffer, e.g. an AutoCAD dwg file is not 100% similar to an exported DXF file, i.e. every file extension conversion is associated with a loss in quality (information loss), similar to the process of copying on a photocopy machine over several iterations. Moreover, software developers, like any other industry are trying to achieve competitiveness by adding extra features to their products. Therefore, there is an inevitable creation of information that can no longer be accommodated in neutral formats or other software formats, (Finch 2000).

1.3 APIs

The use of Application Programming Interfaces (APIs) means that the computer applications reveal some of their internal workings in the form of a hook known as API. If the rules of the API are known, the conversion to any other form is done automatically. Hence, the two applications are able to access and exchange data (i.e. translator). However, due to the wide variety of API protocols used by different applications and the tight definition of the protocol, new versions of the application can ruin the exchange process. The costs of programming expertise required to enable applications to talk to each other in this way are high enough to prevent individual construction companies from investing in it, (ibid).

1.4 Building Object Models

Building Object Models or Building Information Models (BIM) is the paradigm that commercial CAD developers are finally turning on today. (Bentley 2003) (Eastman 1999). Efforts in this field began in the mid 1970s. In the early Models an integrated system supporting building design used to be developed from scratch. Most of these efforts were in the United Kingdom: The first trial was the OXSYS CAD system in Cambridge University. CEDAR and HARNESS hospital design systems. A fourth system was developed to the Scottish Housing authority by Aart Bijl in the University of Edinburgh. Three other efforts were made in the US: The “Techcrete” pre-cast concrete construction system. ARCH- MODEL in Michigan, which evolved into a Macintosh-implemented CAD system and a third in Carnegie-Mellon University by Charles Eastman. At the time of developing these projects the speed of processors and memory capacities were extremely retarded, when compared to today’s. There was no great need to integrate external standard applications, as they hardly existed at the time. More often than not, they were tailored to specific uses and procurement topologies. Thus, they are not suitable for applications out of the scope they were created to serve. To cope with the information technology breakthrough in the last 30 years, and as the construction industry is more and more changing from the art and craft of building to the science of building (which makes the involvement of many disciplines and applications unavoidable), it is becoming inevitable to use building object project models, where the design becomes an information model that can be represented in many different ways (views) to meet information requirements of numerous professionals. Relevant information can be directed to specific areas like estimation, facilities management, project planning and even to more complicated application like aero- and thermodynamics, lighting, acoustics and so forth.

1.5 The Internet

The failure of many BIMs to be adopted by the industry was attributed to the obligation to using a single database approach to the project. e.g. SPACE, 1996 in Salford University. The nature of the industry and the variety of disciplines did not allow such a kind of prototypes to be adopted. The Internet is envisaged to play an important role to solve this problem by representing a virtual database that is accessible to different disciplines in a construction project, in addition to allowing the electronic exchange of data. The Internet’s strength resides in its use of the TCP/IP (Transition Control Protocol/ Internet Protocol) protocols, which are used for communication and transfer of data. TCP/IP enables many different computer systems to communicate together. A PC user can access a document no matter what kind of computer or software created it or where it is actually stored.

After a lot of trials that failed to prove a practical solution to the integration problem or a robust Building Object Model, the ISO[1] started its efforts towards a construction classification system, the application of STEP[2] (ISO 10303-21) and the use of EXPRESS[3] and its graphical representation EXPRESS-G. In

1 ISO: International Organisation for Standardisation

2 STEP: Standard for the Exchange of Product model data

EXPRESS the containing structure is called "*Schema*". Objects are called entities and their properties are represented as attributes and constraints. Furthermore, an inheritance structure is applied through the support of sub-super type relations.

2 IFC

An alliance of over 500 companies called the IAI[4], which was established in 1994, developed and published a building product data definition model called IFC[5]. This model has recently become an (ISO/PAS[6] 16793). Its main objective is to build a universal language to improve communication, productivity, delivery time, cost and quality throughout the design, construction, operation and maintenance lifecycle. The unique characteristic of the IFC is its object description; which does not only preserve the full geometric description in 3D, but also knows its properties and characteristics, e.g. commercial and technical data. The model was developed through several versions, starting from 1.0 to 2x. The IFC 2x platform release is considered to be stable until at least 2005 (IFC 2000). The main advantage of this release is its compatibility with previous releases in addition to the provision of an extensible capability to the model by users.

A large number of Software developers are already adding IFC interfaces as a neutral format for data exchange (Al-Dabbagh et al 2001). Furthermore, XML is the chosen language for information exchange over the web. Software applications are concerned with specific requirements and therefore do not use or implement every class within the IFC model. Hence, subsets of the model are defined in a manner that they can be isolated from the complete model and still act as a coherent model, i.e. views of the model, e.g. CAD, HVAC, FM views (Graphisoft 2001).

The IFC architecture (fig.1) is divided into four layers that use a strict referencing principle. The first (bottom) layer is the *Resource layer*. It provides resources classes used by other classes in the higher levels, e.g. materials and geometry. The second layer, *Core layer,* provides a core project model *(kernel + Core extensions).* The third layer (*Interoperability layer)* is a set of modules that defines concepts or objects that are common across multiple applications. The fourth layer (*Domain layer*) is the top layer. It provides a set of modules tailored for specific AEC domains. The architecture operates on a gravity principle, i.e. at any layer a class may reference a class at the same or lower layer but not from a higher layer (IFC 2000).

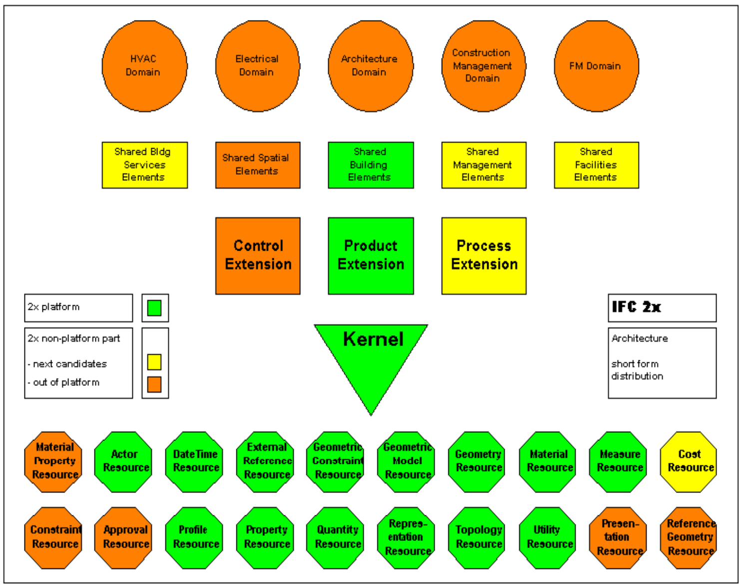

Figure 1 The four layers of the IFC architecture

3 XML

XML[7] is the standard of data exchange over the Internet. However, which schema[8] is to be used or how to interpret IFC objects that are specified in EXPRESS to XML schema? This is a question that has not yet been answered by the industry. There are a lot of xml schema interpretations to the IFC EXPRESS schema, e.g. BLISxml, bcXML, ifcXML and so forth. The problem is that each of

3 EXPRESS: ISO 10303-11 is the modelling language that handles STEP data.

4 IAI: International Alliance for Interoperability

5 IFCs: Industry Foundation Classes.

6 PAS: Publicly Available Specification, (a step before becoming an ISO standard)

7 e**X**tensible **M**ark-up **L**anguage

8 Schema: Model for describing the structure of the information, e.g. types of tags, arrangement and attributes.

which has been written specifically for a certain purpose. They vary from being late binding (LB[9]) to early binding (EB[10]) schemas. The process of interpretation from EXPRESS to XML is called *"Extrapolation"*. This process is done on two phases; the first phase is an automatic 1:1 translation of IFC-Objects specified in EXPRESS to XML. The second step is an optimisation and refinement to solve incompatibility issues between both schemas. This requires different mapping processes in EXPRESS (resulting in several intermediate stages) to change it to a translatable form to XML (Liebich 2001). It is important here to note that XML does not stand for the content of the message, but for the container of the message. XML provides a platform independent and web friendly data structuring syntax for the representation and exchange of data (Burkett 1999).

OIP

In a scenario where a Building Object Project Model approach is applied, every single object would have to be created from scratch, and then, the required properties (information) would have to be added to it. This would be in turn discipline and project oriented. In addition to the time, cost and efforts required for creating a huge number of objects within a construction project. The OIP (Object Information Pack) is envisaged to be produced as a part of the construction product itself in the form of XML or any neutral format. The OIP should be dynamic and flexible enough to include all the technical and commercial information that might be needed throughout the entire lifecycle of the product. It is the responsibility of the manufacturer and the commissioned portal website to continually develop the OIP to be able to satisfy the software applications' need of information. It is assumed to fit into the IFC model through the extension of its layers or to directly instantiate the IFC property sets and relations, provided they are already available within IFC. In this manner, the efforts required in modelling when adopting a Building Object Project Model approach should be minimised, better communication among different disciples should be achieved, in addition to a reduction in cost, time and efforts, i.e. interoperability. This is particularly true when this information pack accompanies a 3D object model within a drag and drop environment over the web. The responsibility of designing and maintaining this OIP could be attributed to the manufacturer himself or allocated to a specialist portal web site (Nour 2001).

Figure 2 shows the process of aggregation of data in a typical scenario, where an Object Project Model approach is applied. The object information pack is produced by the manufacturer according to the specifications and standards (normally the information used to be in product catalogues). The architect or designer goes shopping on the Internet and chooses an object. This object is downloaded to a project library, where it might be used or not. In case it is used, multiple copies of the object can be made throughout the project with reference to the original OIP. The other symbols in the

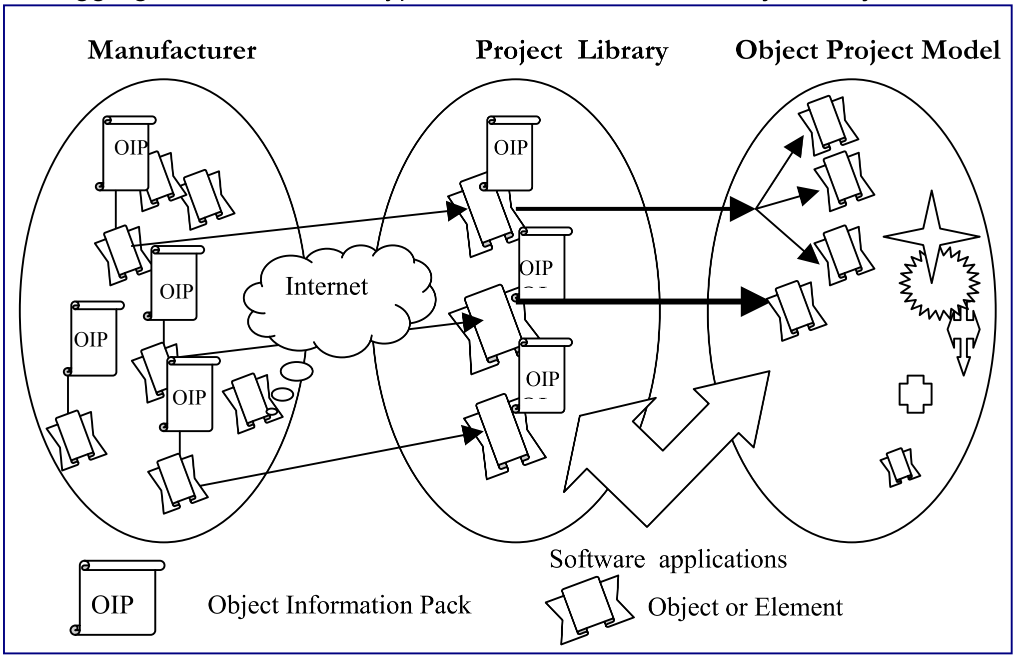

Figure 2 : The transfer of OIP over the Internet to the Building Object Model

9 LB: Late Binding is an approach to specify a single mark-up declaration set that is independent of the EXPRESS schema and can represent data for any schema.

10 EB: Early Binding is the approach where the generation of the mark-up declaration set is dependent on the EXPRESS schema.

third ellipse represent items that are constructed on site. i.e. not downloaded from a manufacturer web site. They would still have to be modelled inside the project. This practise should be minimised with the trend of pre-fabricated structures. All software applications should be able to access the OIP (supporting all disciplines) in the library and extract the required information.

3.1 Example of an OIP

The aim of this example is to demonstrate how an OIP of a simple brick can be designed in XML and aggregated to form an object-building element (a wall). The first step is an analysis to the technical and commercial information offered by national standards and manufacturers. An example of an output of this aggregation of object information using XML is the production of tender documents (Bill of quantities and Specifications). A comparison with IFC is held to determine to what extend can the model accommodate the OIP and which parts of the model need to be further extended.

In this paper the example is very briefly described, just to give a rough idea about the transfer and aggregation of information. The result of the analysis stage is data that needs to be captured for both the brick (OIP) and the wall building object element.

The brick information normally includes: A serial number, Manufacturer's name and contact details, description of the product, material, working dimensions, dimensions accuracy, texture, colour (image), conformance to standards and classification systems, bulk density, mortar mix, voids %, geometry, maximum compressive strength, water absorption, thermal conductivity, package size, EOQ (Economic Order Quantity), delivery lead time, and price. These are the main properties of the brick that have to be communicated as an integral part of the product.

A wall (Id), location, composition (single or multiple wythe[11] (solid or cavity wall, structure of layers and so forth)) are usually determined in the CAD environment. Dimensions and functions (face work, load bearing, free standing, retaining) are determined with reference to the brick. In this manner simple parameters such as volume, surface area or number of bricks can be calculated. Also the weight, bearing capacity and heat transfer of the wall can be determined. As the model grows and more aggregation of building elements is achieved, further applications can make use of it without having to re-key information.

By inspecting the IFC model and to which extend can it support the above mentioned simple aggregation, it was found that: There is no such thing as "ifcBrick" element. In order to solve this issue, either the brick has to be identified as a material in the resource layer and then associated by relation to the "ifcWall" element at the interoperability layer or the model can be extended at the core layer to include it as a subtype "ifcBrickwall". According to the IFC extension-modelling guide, the first approach is preferred. Concerning the structure of the wall, the IFC does not contain a multiple wythe wall or a wall with a cavity. Again this should be achieved by adding a subtype or by relating the wall to the material layer set in the resources layer of the IFC.

In conclusion, OIP is a new approach trying to automate the process of developing a Building Object Project Model, by offering ready made objects that are not only 3D CAD blocks (objects), but also a whole range of information that might be encountered in the product's whole lifecycle. This pack of information should be compatible to the IFC model and capable of being transferred over the web. It is envisaged that many applications can benefit from the information available in the IFC model, e.g. Virtual reality "Walk through" applications for marketing purposes. In the mean time it seems to be a great chance for expert systems to work on detecting the resulting overall characteristics of the model, according to the combination of its elements. The model could also be tested against real life factors e.g. earthquakes, sound, energy simulation and so forth. Another important point is testing the compatibility of elements at critical interfaces and whether they fit together or not, e.g. how does a window detail co-ordinate with a curtain wall system. Another example is in Facilities Management, the OIP could contribute to the automation of production of hand over information. Expert systems might

[11] Wythe: Layer of a wall.

also be able to predict health and safety instructions, when certain objects are related in a particular order or structure.

One of the critical problems that has been discussed by Howard (1998), and Finch (2000), is the increase in standardisation, due to the use of ready made models possessing their information supplements. The awkward question here becomes; how can it fit with the principle role of the designer as an "idea generator" and "creator"? the designer will be able just to make decisions of selections, drag from a library and insert in appropriate place according to a design concept and plan.

It is expected that in the near future, the whole process of commissioning buildings will be pre-assembling them as models in computers and handing them over to their user in an electronic medium, including the guiding instructions that supports managing construction operations like a factory (Howard 1998).

Another critical problem that might arise from the use of an (a to z) electronic building commissioning is that the skill of the architect in creating new opportunities and logical spaces is often not fully valued by people who might think themselves able to draw and select objects to end up with an electronic model which is directly delivered to a contractor. In addition to the presence of already designed standard houses on the Internet (ibid).

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