Implementation of Single Building Modelling Technologies into the Management Phase of the Property Cycle

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Abstract

This paper brings together work carried out by Guy Hazlehurst, Stephen Drewer and Roden Buxton at the University of the West of England on the concept of the Single Building Model and research by Terry Pitt and George Griffith on the management of complex healthcare facilities, 'Healthcare FM'. The central aim of the research has been to utilise advanced 3D, object models of complex buildings not only as repositories for 3D, 2D graphics, data and intelligence, but to act as 'information brokers'. The concept of the single building model has effectively evolved to provide a spatial database that has the inherent potential to act as the spine of a 'heterogeneous' system. This spine links the sub-systems that enable complex processes throughout the life of the building to be modelled.

This paper will seek to address the issues of systems integration, through the creation and application of Single Building Modelling technologies, during the post occupancy stage of the building process. Modelling complex buildings and estates at a time long after the facilities were originally conceived, designed and built posits a set of unique issues that do not arguably arise when such models evolve through the incremental processes of inception, design and construction.

It will be argued that the principal issues are those of data compatibility and the level of detail required within the 'ex-post' single building model to deliver optimum benefit to the owners and managers of complex buildings. The research issues identified by the production and implementation of such a model within a Hospital's existing building management will be discussed. Although the example cited in this paper is a healthcare building the points raised within it arguably apply to any significant property or estate.

Introduction

As long ago as the early nineteen seventies there have been drivers for change towards a more integrative approach towards the way that information is handled throughout the design, construction and management phases of the building process. Information and communications technologies were seen as the catalyst to achieve this form of integration and on a minority of very large and complex projects these aims have been championed through the development and implementation of systems such as RUCAPS, EDS and SONATA.[1]

The usual implicit or explicit goals for use of such systems were to reduce costs, increase quality, use time and resources more effectively, and to explore more options[2]. There was substantial commonality in how these goals were to be achieved. The aims were to:

- Improve collaboration between the main actors in the process, by providing a common focus for information flow, leading to improved integration between different applications, users and beneficiaries;
- Improve insights into the intricacies of design, management and construction, through enhanced design analysis and detailed feedback;
- Improve the decision making process by automating the handling of objective criteria leaving designers free to concentrate on the important subjective issues involving informed value judgements;

- Automate and improve the integrity and validity of project information through the capture of data at source;
- Increase the ease of use of systems and information, through incorporation in the system of procedures and practice clearly understandable and deployable by all;
- Increase participation in decision making by building occupants, partly by greater 'experiential appraisal of the qualities of the environment'.

The mechanism making all these ends possible was seen to be a fully integrated information repository, which is described here as the 'single building model'.

Despite the industry's historical interest in the implementation of such systems, in reality they have only tended to have been used on the largest and most high profile construction undertakings. The arguments for this are based on a complex set of issues and problems that are the focus of other research into this area. The arguments for the industry's slow acceptance of integrative information technologies to achieve these aims are based partly on the high cost of implementation and the complexity of the industry itself with respect to industry structures and existing practises[3].

It has become common to talk about the above concepts as 'Single Building Modelling' and whilst this area of research is now becoming 'mature', there appears to be a gap in our knowledge on the application of such models in the management phase of the property cycle. This may be attributable to a tendency to view the building process as an incremental, linear process, starting from inception and design; rather than a cycle in which design, construction and management issues are continually being revisited during the life of the building. This argument relates to the concept of the building as a set of 'Time dependant services' [4] and the need for facility's to physically change and adapt to meet users and owners needs.

The research underpinning this study focuses upon the modelling of a hospital that was originally built in 1974, St Michael's Hospital in Bristol, UK. This hospital, which has a floor area of 16000 square metres and caters for 50,000 bed days per year, is part of a larger estate of hospitals that are owned and managed by the United Bristol Healthcare Trust. Management of the estate has traditionally been carried out through hierarchical management systems. The aim of the research was to encapsulate the hospital within a single building model and to explore the potential benefits, limitations and mechanisms through which the model could be used to facilitate the integration of information relating to the future design, alteration and management of the building.

The aim of this paper is therefore to articulate a more thorough understanding of the benefits and limitations to building owners, facilities managers and users of implementing such systems at a stage that is 'ex-post' to the processes of design and construction , rather than 'ex-anti'. The latter having previously been the main focus of research activity in this field.

The concept of the Single Building Model

The aim of the single building model, in this context, is to represent 'the entire building' within an integrated system that makes optimal use of information technology to exchange data on the building product to all interested parties. Through effective integration of data, the model acts as the sole, 'virtual' repository of information relating to the building during the period of design and construction, or in to the projected life of the building.

All of the parties involved in the design, construction and management system contribute to, and take information from this 'single building model' (Svennson)[5]. The data is presented to the building professionals and engineers in a way that best suits their needs at a given time in the life of the construction product. The nature and quality of the information presented by the model will also be dependent on the role and function of the person interrogating the data.

Large advances and substantial reduction in costs of computer hardware and software now mean that the applied use of such models is now economically viable for complex and relatively expensive buildings or estates. Examples of projects to which these technologies are currently being employed include airports, oil and chemical installations, hospitals, tunnels and large industrial construction projects.

Single Building Models and Accommodation of Change Through the Life of a Building

The property cycle (see figure 1)suggests that an organisation should be constantly reviewing its portfolio and each property within the portfolio continuously going through the cycle. This cycle starts with a need for space. This need can be met by acquisition, modification of existing or new build. If the chosen path is modification of existing or new build then the cycle goes through design and construction before commissioning and use. If the space is acquired then the organisation is only directly responsible for commissioning and use. Any design and construction will be the responsibility of third parties. During use the property is subject to maintenance and possibly modification, refurbishment and rehabilitation. At the end of its use the property can be mothballed, disposed of or demolished.

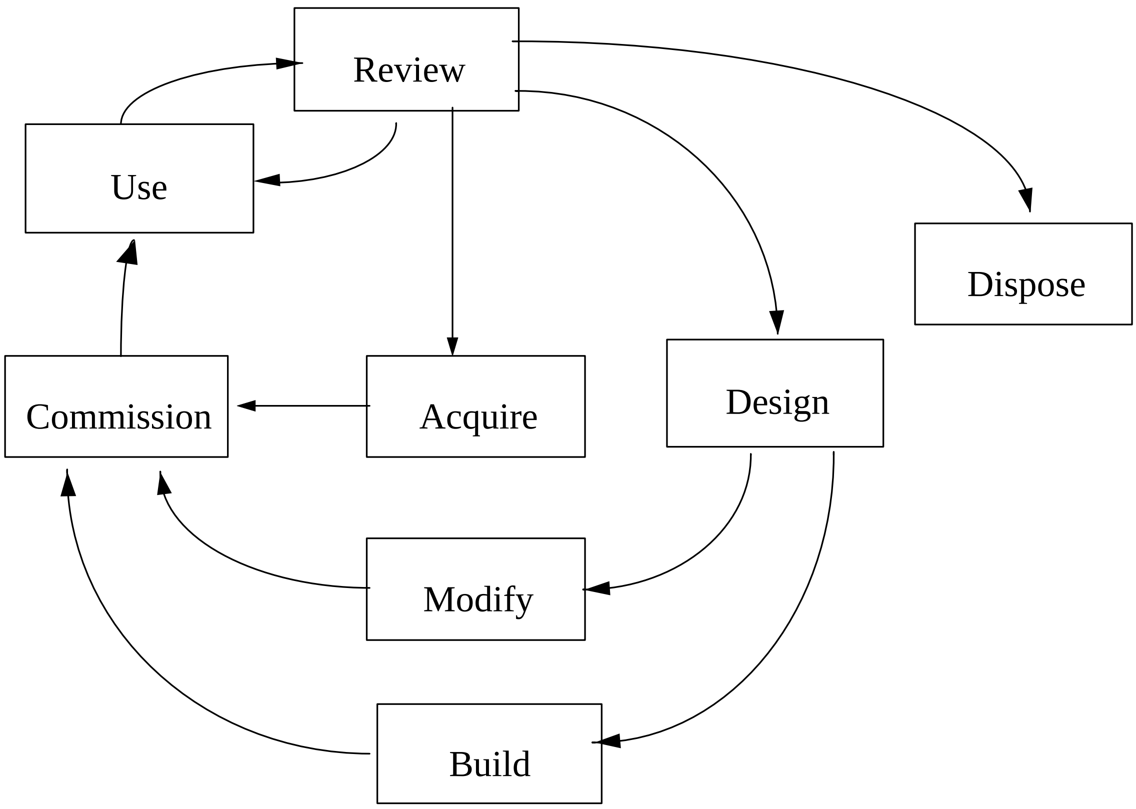

Figure 1 The Property Cycle

Each event in the cycle can be further sub-divided into activities. For example design could be sub-divided into feasibility, planning approval, sketch design, detailed design and procurement. Each of these activities could have different players, in deed, it is possible that individual activities might have more that one player. An illustration of this is that the detailed design could involve architects, landscape architects, structural engineers and building services engineers. Each of these players is likely to have an information system that is appropriate to their task and the event in the property cycle. That is there will be numerous information systems associated with a property. Traditionally it was difficult to transform information between systems. Experience also suggested that each time information was transformed its reliability and veracity became questionable, and the more times information was transformed the more questionable it became.

The suggestion is that if each piece of information within each information system is contained within, or attached to, a single three-dimensional object within the single building model, then the information does not have to be transformed but can be viewed ‘transparently’ within the model, or from one information system to another. The use of data through this view is referred to as “brokering”.

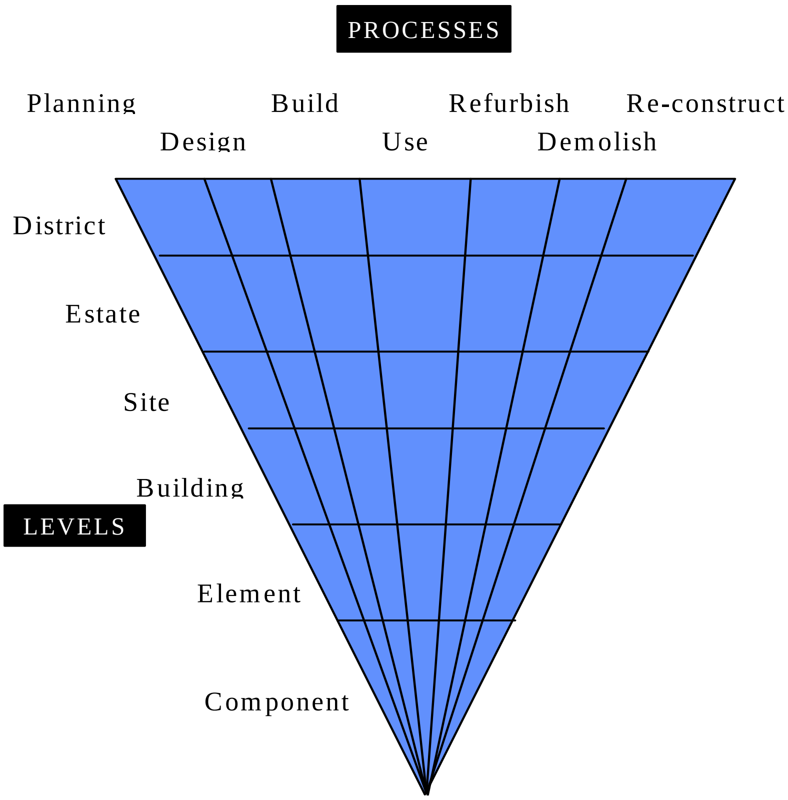

Figure 2 The Process Model

A further suggestion is that if there is three-dimensional encapsulation in the model then it is possible to appreciate the location of any entity in relation to any other entity. As a consequence of this appreciation any required aggregation or dis-aggregation can be undertaken. This approach is illustrated in figure 2. The integration of traditionally ‘isolated’ and disparate information systems through the single building model thus enables the potential for fully co-ordinated, and ‘up to date’ building information. The reliability of such data has, in the past, been seen as a key inhibitor to the effectiveness of the management decision making process in large and complex estates (University of Salford et al.)[6].

The Suitability of Single Building Models for Information Brokering

The information management system that lies behind the single building model is an ‘object oriented’ database. This is a database in which the information is represented in the form of classified objects and relationships between these objects. An object, or building component, is characterised by its ‘attributes’ and corresponds to phenomena in the reality that the database represents. In the case of a building this is its genesis, production and use.

The data structure and classification used in single building models makes it possible for the building as a 'physical entity' to be sub-divided in to aggregated, physical entities or systems. These may include floors, telecommunications installations, lift installations, ducting networks and dis-aggregations of these systems, to the level of the individual component. The structure of data in the system therefore enables information regarding different sub-systems within the building to be kept together and manipulated at different stages of the building process, from inception through to building use.

In the traditional construction process, work on the design and production of buildings has also been based on 'objects' such as walls, floors, windows, heating systems and the sections of work that are comprised in the construction of these building 'elements'. These are 'objects' that are first designed, drawn, procured and built. It is therefore a natural, computational step, to use an object oriented approach to the design of computerised building product models

Throughout the design, construction, management and use of a building there is therefore a need to interpret different types of information that can all be stored as attributes relating to a single 'object' within the system. By way of example, it is spaces and functional systems that are of importance to the client and designer at the initial design phase.

During the construction phase it generally becomes more important to be able to work with typical object types such as subsystems and components. Finally, in the management phase, the information requirement is again biased towards entire functional systems, spaces and their use and adaptation over time.

The concept of how we view the building changes however from the perspective of the building managers, owners and facilitators. In these cases it is not so evident that building elements and work sections should be regarded as 'objects'. Tasks and activities during the operation and maintenance of the building are related to the concept of the building product as a 'set of time dependent services'. Information required by these parties is therefore associated with different spaces within the building and their use over time. Examples of these spaces are rooms and building storeys. In the majority of such cases it is the 'function' of systems within the building that are of importance and not the physical inter-relationship between building components.

In this way single building models have the potential to accommodate and facilitate the interaction between 'hard' and 'soft' technologies that are encountered during the process of design, construction and management of the building process.

St Michael's Hospital - A Case Study on the potential of 'Brokering' Building in Use Information through the Single Building Model

The concept 'Buildings in Use' is one that is generally accepted as being of importance when considering the life cycle of buildings. The concept centres on Stone's definition of 'cost in use':

> *The costs...include: the costs of acquiring, cleaning and developing the site; the costs of erecting the buildings; planning, design and other fees and interest during development; the cost of maintenance (replacement of components, repair and decorations), conversion and modernisation; cleaning, heating, ventilation and lighting and other service costs; and the costs of sale or demolition.*

From this definition there are clearly three distinct areas to the costs in a building's life, these being; Design and construction; Use; Sale, or Demolition. This case study is primarily concerned with the second phase. Seeley refers to the costs of these as the 'User Costs', and considers them to be split into two different types, 'Running Costs' and 'Occupational Charges'. 'Running Costs'

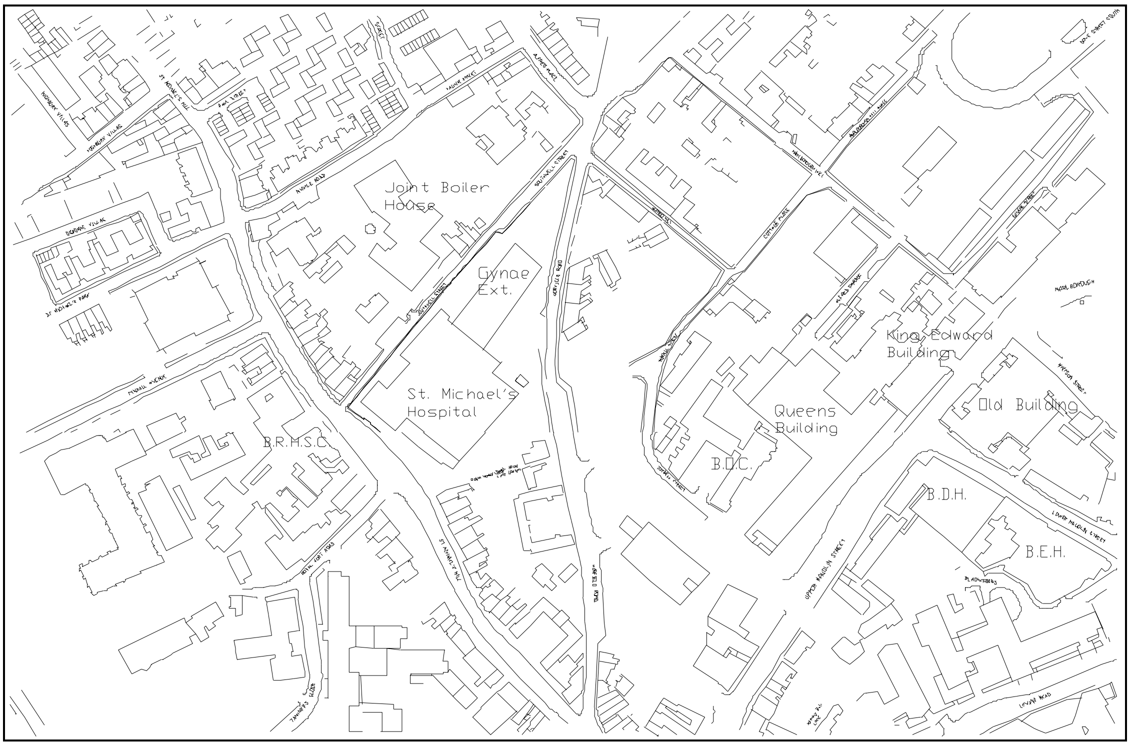

Figure 3 Bristol Royal Infirmary Precinct

encapsulates maintenance, operating services and energy costs, whereas 'Operational Charges' include rates, property taxes, insurance, modifications, alterations, estate management and control.

St. Michael's hospital was chosen as the case study as it is relatively 'self sufficient'. Despite this cost in use data is available at different levels. For example costs such as rates, steam energy and overheads relate to the precinct level (see figure 3); capital charges, planned maintenance, electricity and gas relate to the hospital level (see figure 4); occupation and function relates to the room level (see figure 5); reactive maintenance to component level (see figure 6).

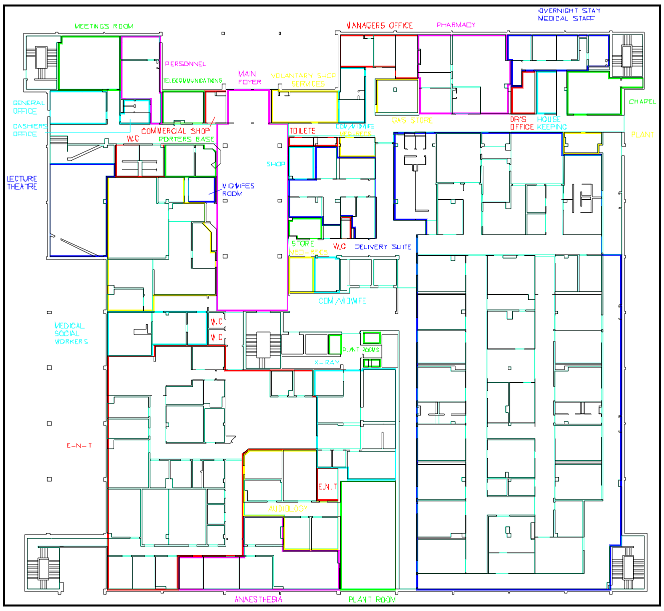

Figure 4 St. Michael's Block 1

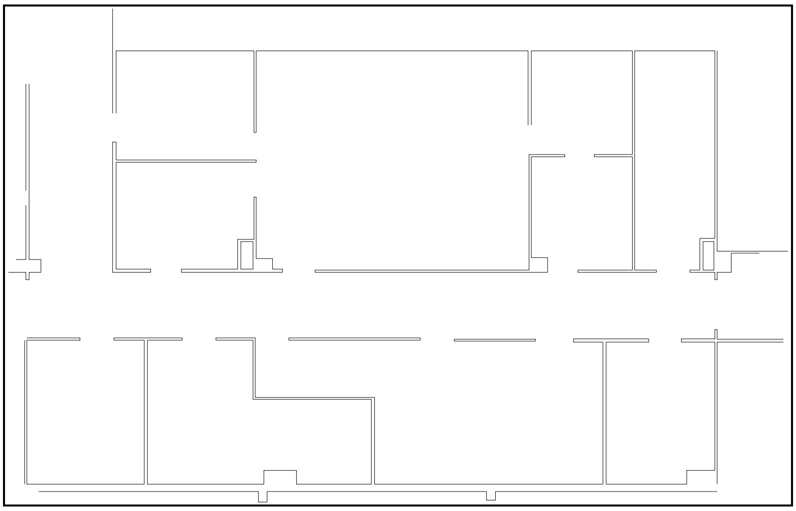

Figure 5 St. Michael’s, rooms on level D

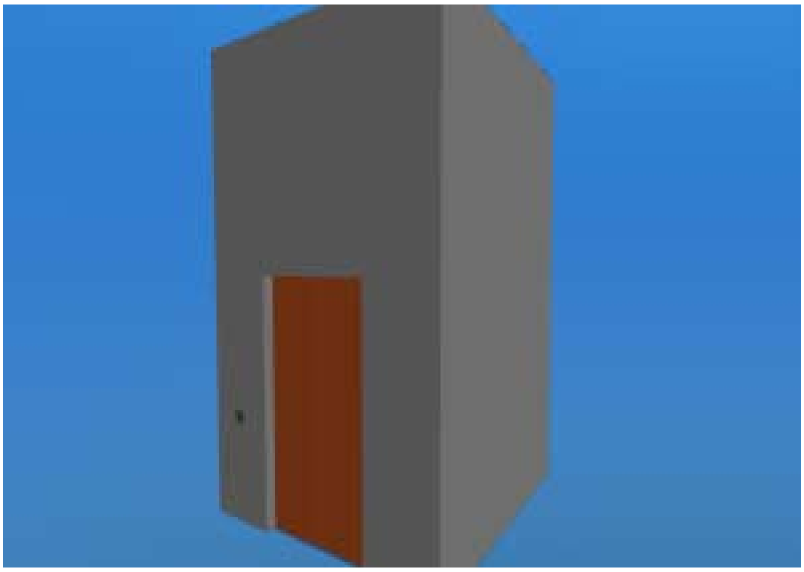

Figure 6 St. Michael’s, Lift Component

Pitt and Griffith (Helsinki) argue that an efficient method of relating data that is naturally stored at different levels is to create a spine based on a spatial database (see figure 7). The spatial spine can be effectively delivered using the single building model.

Three Dimensional Modelling - Approach.

When 3D modelling is commenced from the inception of a new building, the content of the model can be planned to serve the various stages such as outline design, statutory approvals, detail design and construction information. A model that has evolved in this way should be suitable or readily adaptable as the spatial database that links heterogeneous management systems throughout the life of the building.

Requirements are significantly different when modelling commences after the building has been constructed, they are in some ways less rigorous as, for example, the model need not contain construction information but it may be used in the event of internal alterations or extensions. Because of the difficulty of predicting events over the lifetime of a building, one must expect the modelling requirements of an existing building to be just as difficult to define as those for a proposed building.

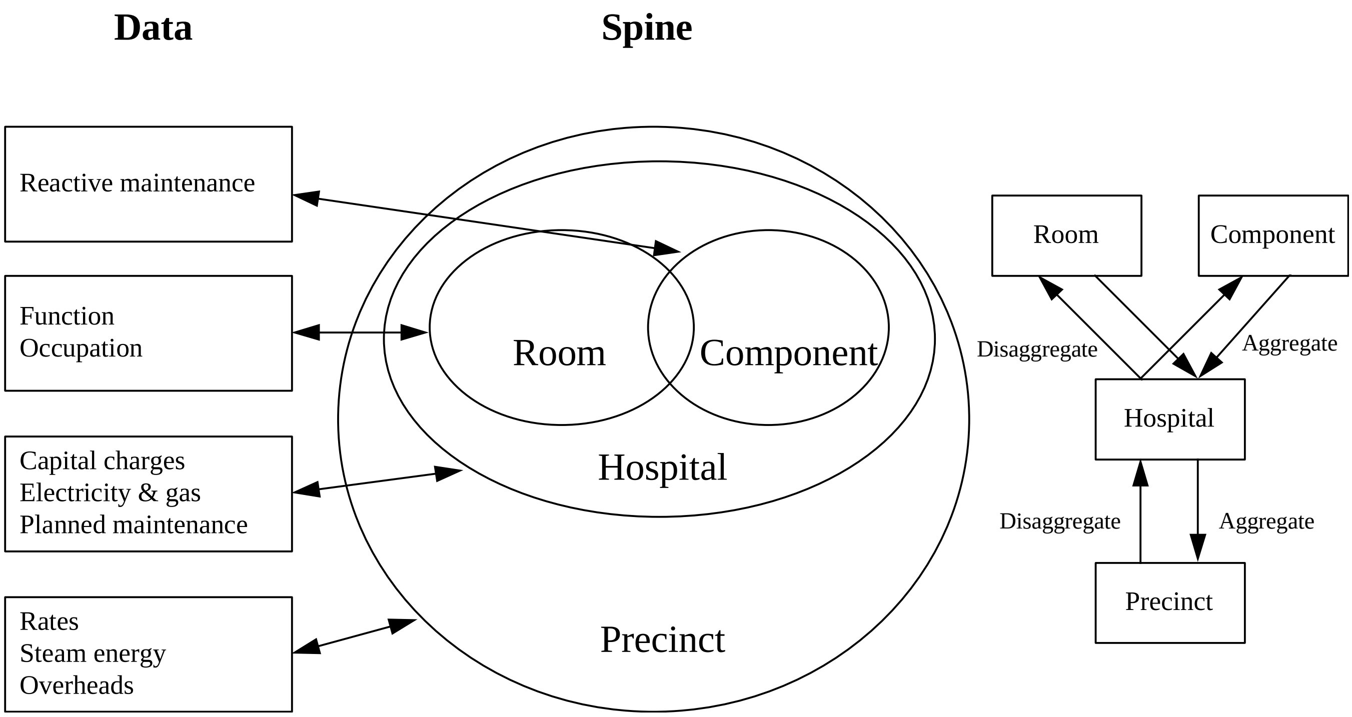

Figure 7 Structure of Spatial Spine

When no 3D model has been produced as a result of design and construction, the question is whether the benefits to building management justify the cost of a model produced for that purpose alone. At present the question is debatable but, as technology advances and costs decrease, the question may arguably become 'can one afford not to have such a model?'.

Lessons learnt from the modelling of St Michael's Hospital suggest that the ultimate cost-benefit of re-modelling a building 'ex-post' depends on minimising the modelling cost and on making imaginative assumptions about the potential present and future uses of the model. In the case of the existing hospital buildings the modelling cost was found to be most sensitive to three factors: the method of data input, the dimensional accuracy and the graphic realism required of the model.

Three Dimensional Modelling - Data Input

When modelling an existing building, such as St Michael's, data may be obtained in one or more of the following ways:-

- Site surveying methods ranging from manual to automated.
- Hard-copy drawings to be translated by the CAD operator or scanned as bit-mapped images and used as 'templates' for the modelling.
- Digital drawings (usually 2D) that may be imported as vector data.

The research involved modelling the existing building through existing hard-copy 2D drawings. This was arguably more efficient than obtaining all the data using current site surveying methods but much supplementary site surveying was necessary. The hospital pre-dated CAD and digital drawings were not available.

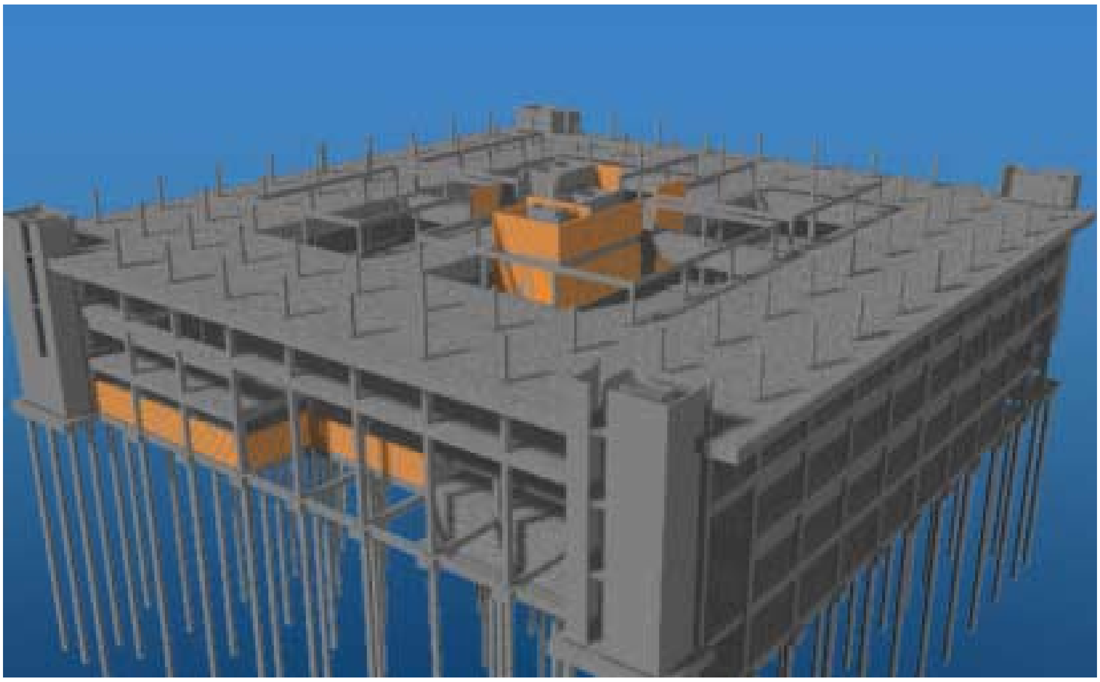

Figure 7 3D Perspective of Structural Elements, taken from the St Michael's Hospital Model

If such drawings had been available, one might expect that 2D digital drawings would save a lot of time but the output of most 2D and 3D CAD software would only be usable as background templates over which to commence fresh modelling. This is because much CAD, due to its design or poor implementation by the user, is used as a mechanised drawing board and the drawn elements cannot be automatically translated into the 'intelligent,' 'parametric' and other featured elements that are characteristic of modern object-based 3D modelling programs.

Due to this and the numerous deficiencies in the hard copy drawings it was not considered worthwhile to scan them for use as background templates and they were interpreted visually by the CAD operator. The main difficulties that were encountered as a result included:

- The interpretation of unclear or conflicting drawings.
- Information within the 2D drawings not being in a form that adequately defined the 3D objects required in the single building model.
- The presence of conflicting or absent dimensions.

Even without such difficulties this 'manual' data entry was surprisingly time consuming due to 'usability' limitations of the single building modelling software. However, these problems would arguably be just as prevalent with most of the CAD products on the market today.

Three Dimensional Modelling - Dimensional Accuracy

There is no significant limit to the potential accuracy of the software used to model St Michael's Hospital, whereas in the case of most buildings it would be quite normal for distances of, for example, 3 metres to deviate by 10mm or more from the dimension implied by the drawings.

It is arguably of little use to achieve greater accuracy in the model than can possibly have been achieved in the finished building, particularly when excessive accuracy is likely to raise the cost of the modelling. Alternatively, a high level of accuracy within the model can save time by allowing repetitious elements to be copied and re-used. This does not require the model to be accurate in relation to the building but may result in some inaccurate assumptions about the building being applied uniformly.

CAD programs normally allow 'freehand' location of points using a pointer, which tends to be inaccurate, or keyboard entry that offers unlimited accuracy but is very laborious. CAD programs do not generally offer much between these extremes. One of the drawbacks of keyboard entry in CAD is that, unlike manual drawing, one cannot vary the accuracy, and hence modelling time and cost, on a sliding scale.

In the case of St Michael's it was decided that the model must be sufficiently accurate to be used in the future re-design, alteration and refurbishment of the building. In order not to compromise these future uses of the model 'global' dimensions such as the grid, structure etc. should arguably be as close to reality as possible, whereas the locations and dimensions of subordinate components can be approximated within limits. Provided that the modelling software permits global exchange and enhancements of such elements it should be a simple matter to improve the overall accuracy of the model by substituting more accurate elements when the used for re-development purposes.

Issues of 'Fitness for Purpose'

The labour cost associated with the creation of 'ex-post' the model and, not so obviously, the hardware and software costs, are proportional to the graphic realism of the model. As a result it is relatively easy to include information to the model that may be regarded as superfluous detail if the main purpose is to utilise the 'ex-post' model as a heterogeneous spine to integrate management information relating to the building.

The inclusion of superfluous detail in pursuit of realism clearly extends the data input time and hence the principal cost. However the consequent larger digital model occupies more storage media, requires a faster processor and/or more RAM to process and requires faster graphic display devices all of which add also to the hardware cost.

If, as in the case of St Michael's, the main purpose of the model is to act as an 'Information Broker', simple shape representations, often using colour rather than vector differences to make physical and spatial distinctions, can achieve a realistic and useful display. This approach minimises the initial cost of a model through the simplification of all elements. Building components that are frequently repeated in the external envelope and the internal subdivision of the building should be represented by the simplest 'bounding box' that defines the perimeter of the component with the minimum of detail within. Extensibility of elements within the model and the capacity to implement 'Global Exchanges' at a later date, does not proclude the model from effective use when parts of the building are inevitably re-conceived and re-developed.

The model therefore starts at a level of detail, appropriate to the integration of the management functions related to the building. This will ensure that the user achieves optimum functionality at minimum cost. As the building process is re-visited in different areas of the building, the model evolves in detail and value through the extensibility of the parametric objects within the model.

Conclusions

Recent developments in Hardware and Software technologies have resulted in fully integrated, virtual repositories of building information becoming a reality. However, the application of 'Single Building Models' and the associated technology has tended to be focused upon the design and construction phases of the construction process.

As we move towards the concept of the 'Single Building Model' and it's extended role within the entire property cycle, it is arguably no longer appropriate to regard the model as the sole repository for building information. Integration of existing property and management information may,

instead, be facilitated through a more 'heterogeneous' approach, using the model as a spine to 'broker' information about the building to the various interested parties.
When modelling an existing, complex building, 'ex-post' to the processes of design and construction, the most sensitive factors have been shown to be:

- The method of data input.
- The level of dimensional accuracy .
- The graphical realism required from the model.

The importance of each of these aspects depends on the various applications that the model is expected to serve. For example, if the main aim is to use the model as an 'information broker', a high level of graphical realism is not necessarily of primary concern. However, the model should start at an appropriate level that achieves optimum functionality at minimum cost and as the building is re-visited the model can evolve in detail. In order to achieve this, and to avoid compromising the model's future use, 'global' dimensions, such as the grid and positions of main elements, should be modelled as close to reality as possible.

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