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Building Information Modelling for FM at Sydney Opera House

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Executive Summary

"SOH see significant benefit in digitising its drawings and operation and maintenance manuals. Since SOH do not currently have digital models of the Opera House structure or other components, there is an opportunity for this national case study to promote the application of Digital Facility Modelling using standardized Building Information Models (BIM)".

The digital modelling element of this project examined the potential of building information models for Facility Management focusing on the following areas:

- The re-usability of building information for FM purposes
- BIM as an Integrated information model for facility management
- Extendibility of the BIM to cope with business specific requirements
- Commercial facility management software using standardised building information models
- The ability to add (organisation specific) intelligence to the model
- A roadmap for SOH to adopt BIM for FM

The project has established that BIM – building information modelling - is an appropriate and potentially beneficial technology for the storage of integrated building, maintenance and management data for SOH.

Based on the attributes of a BIM, several advantages can be envisioned: consistency in the data, intelligence in the model, multiple representations, source of information for intelligent programs and intelligent queries.

The IFC – open building exchange standard – specification provides comprehensive support for asset and facility management functions, and offers new management, collaboration and procurement relationships based on sharing of intelligent building data.

The major advantages of using an open standard are: information can be read and manipulated by any compliant software, reduced user "lock in" to proprietary solutions, third party software can be the "best of breed" to suit the process and scope at hand, standardised BIM solutions consider the wider implications of information exchange outside the scope of any particular vendor, information can be archived as ASCII files for archival purposes, and data quality can be enhanced as the now single source of users' information has improved accuracy, correctness, currency, completeness and relevance.

SOH current building standards have been successfully drafted for a BIM environment and are confidently expected to be fully developed when BIM is adopted operationally by SOH.

There have been remarkably few technical difficulties in converting the House's existing conventions and standards to the new model based environment. This demonstrates that the IFC model represents world practice for building data representation and management (see Sydney Opera House – FM Exemplar Project Report Number 2005-001-C-3, **Open Specification for BIM: Sydney Opera House Case Study**).

Availability of FM applications based on BIM is in its infancy but focussed systems are already in operation internationally and show excellent prospects for implementation systems at SOH.

In addition to the generic benefits of standardised BIM described above, the following FM specific advantages can be expected from this new integrated facilities management environment: *faster and more effective processes*, *controlled whole life costs and environmental data, better customer service*, *common operational picture* for current and strategic planning, *visual decision-making and a total ownership cost model*.

Tests with partial BIM data – provided by several of SOH's current consultants – show that the creation of a SOH complete model is realistic, but subject to resolution of compliance and detailed functional support by participating software applications.

The showcase has demonstrated successfully that IFC based exchange is possible with several common BIM based applications through the creation of a new partial model of the building. Data exchanged has been geometrically accurate (the SOH building structure represents some of the most complex building elements) and supports rich information describing the types of objects, with their properties and relationships.

1. Introduction

This document discusses the existing systems to manage assets at Sydney Opera House (SOH), the concept of a Building Information Model (BIM), the complementary data sharing standard Industry Foundation Classes (IFC)[1], the standard's functional support for asset and facility management functions, and finally gives an overview of some commercially available IFC compliant asset and facility management (AM/FM) applications, identifies key findings and makes recommendations for BIM at SOH.

2. Facility Management Systems at SOH

2.1 Existing AM/FM Systems

Current systems at SOH are as follows:

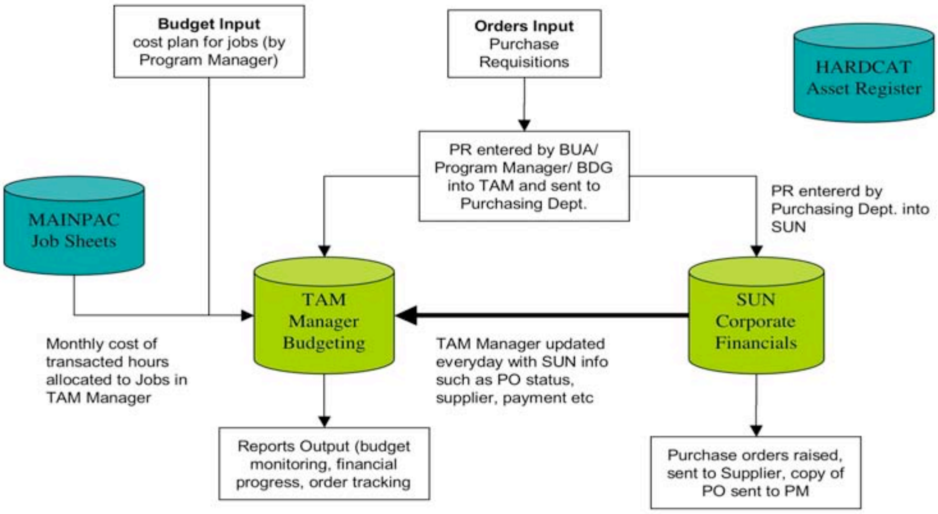

Figure 1: Existing AM systems

Function	Product	Comments
Building maintenance	**MAINPAC**	Job sheets, recording labour/hour transactions are managed by the system. Records performance measures (eg average time for alteration etc)
Asset Register	**HARDCAT**	The financial asset register, which monitors the value of the asset at any given time. Uses depreciation rates to calculate current value. Annual asset audits are performed through this system.
SAM Budgeting	**TAM Manager**	System established in 2000, with data from 2001 to date considered reliable. Setting up and monitoring of major and regular works budgets, order commitments

[1] ISO standard ISO/PAS 16739 Industry Foundation Classes, release 2x, Platform Specification (IFC 2x Platform).

		and actual spend. Ensures that projects are completed within the allocated budget.
Accounting	**Sun**	Corporate Financial system
Building Condition	**FaPI**	SQL database, updated weekly or quarterly with a rating of the presentation of the building.
Document Management	**TRIM**	Business document management tool. (Adapted by the Facilities Portfolio as an interface to SOH pdf drawings linked to an MS Access database)
Technical Document access	**Intranet**	An Intranet is being introduced to provide universal access to SOH technical information

Table 1: Existing FM Systems

2.2 Assets

An asset is anything with a value of greater than A$5k. All assets are bar-coded (approximately 7500 in number).
Currently assets are classified according to 14 functional zones (FS, see below). The level of detail is determined by the frequency of activity (e.g. lifts are identified individually because of the volume of repair).
An asset audit is carried out annually.

2.3 Maintenance

Maintenance is complicated at the Sydney Opera House due to the nature of the building, a high level of building services and operational requirements which severely limit access to operational areas.
Maintenance is divided into two categories *Preventative* and *Corrective* (ad hoc).

A key element of the maintenance services is the Operations Centre which is the first point of contact for any problem on the site. 10-20 corrective jobs are carried out daily, with approximately 200 jobs total per week.

40 external staff and 25 in-house staff are employed on maintenance.

Maintenance is organised into four technical groups:

- electrical
- mechanical (including stage gear etc)
- building
- CAVS (communications and audio–visual services)

2.4 Statutory Compliance

The building is required to be certified for Place of Public Entertainment (POPE) and much change has occurred to these regulations since the building was originally commissioned.

BCA compliance is also required with significant impact in public areas (such as egress lighting etc.)

2.5 Building Presentation

To address the ageing of the facility (almost 30 years of intense usage) a measure of the visual presentation of key public areas has been established, as part of a priority asset management initiative. Technical standards have been developed (building presentation index BPI) to regularly monitor this aspect.

Contracted maintenance work incorporates this requirement, though self inspection and SOH audits.

2.6 Strategic Plan

A 25 year strategic plan is in place, with an estimated yearly 2006-2007 to 2030-2031 budget of $51m (average per annum, estimated and escalated).

The current approved maintenance budget is however $19m, with a breakdown as follows:

- regular maintenance $8m
- major works $11m

For regular maintenance $5m is carried out on contract, with $3m by SOH in-house team.

2.7 External Services

The ongoing planned maintenance services are undertaken by external Contractors for each of the four technical elements, e.g. electrical, mechanical, building and CAVS.

Contractors are engaged on term contracts.

Currently none of the AM/FM systems are integrated. Although not integrated, consistency is maintained between systems.

There are no connections to the four main external contractors and all updating of SOH AM/FM data has been done to-date manually by SOH staff. Outside contractors are now required to use in-house systems, reducing this waste of resources.

A future system would permit direct sharing of data and updating.

3. Building Documentation Management

3.1 History

Commencing in 1958, the project documentation was based on hardcopy paper and pencil/ink drawings, pre-dating even the introduction of 2D CAD technology. While excellent catalogues of this information are available, accurate data is extremely limited, in either hardcopy, microfilm or digital format.

At the end of Stage I of the construction in 1966, accurate surveys (in decimal feet units!) of the then current infrastructure of the ground works and podium was carried out and to date these are the definitive data of those parts of the building.

3.2 Nature of the Sydney Opera House Building

As the exterior of unique curved shells implies, the Sydney Opera House is a large, very complex structure, housing equipment and activities that are equally complex. The building comprises 7 theatres, 37 plant rooms, 12 lifts, over 1000 rooms; the building has 300 full-time staff with 500-600 part-time staff, delivering over 2500 performances per annum.

The building has a design life of 250 years and a very high quality of construction and finish appropriate for NSW’s most prestigious entertainment facility.

The building has a Conservation order and is likely to have a UNESCO World Heritage listing, further complicating the process of change and renewal.

Its early structural and spatial layout were a design challenge for the design and construction team, and innovation was a common theme of the eventual technical solution for many aspects of the final design.

The consequence is that traditional 2D documentation was hard pressed to adequately describe the work to be constructed; and although this may have been rather more adequately resolved by the geometric capability and accuracy of 2D CAD software, unfortunately the building construction pre-dated the emergence of this technology.

3.3 CAD Drawings

The final drawings were converted to CAD (by tablet digitisation of the hardcopy plans) in the late 80s just as this technology was becoming adopted in the industry. However, for example, floor plans converted at that time are unreliable and are not co-ordinated over different levels.

Consequently all works that need accurate descriptions of the existing building have to be re-measured by the relevant contractor carrying out the work. This has lead to a significant degree of wasted work, and should be addressed in any new documentation initiative.

The lack of consistent, reliable data has become a major problem after 30 years of occupancy, particularly many services system modifications, numerous small works projects and now, the need for significant renewal and related building updates.

Redevelopment of the Base building is hampered because of the poor quality of CAD data.

To develop a 2D CAD database today requires a major investment as the foundation of this work will be a complete re-survey and re-documentation.

3.4 Survey Markers Project

To address the lack of good drawings and to develop a strong platform for future work, a series of survey marks (169) have been established, with brass pins identified by the location (see **BIMSS: Coordinate System**, p4) and geographic coordinates. This will ensure accurate placement of new work and guide all future measurement and technical documentation.

3.5 Digital Models

SOH has no current digital model data (BIM) of their facilities. However a significant model has been prepared by Arup, as part of their work on the new Opera Hall upgrade (see later detail on this information).

3.6 Facilities Plan Room

The Plan Room has a very well managed microfilm store (~30,000 records), which has been thoroughly indexed. An extensive set of survey, original design and building services drawings are available, although they are predominantly design documents.

Recently the key parts of the microfilm archive have been converted to pdf format, and are available in a preliminary version on an intranet for all SOH Facilities staff.

A comprehensive and developing set of documentation, building and related coding standards have been established (see BIMSS Report). This incorporates fire zones, room naming and door identification, etc.

A penetrations database (at firewalls etc.) is established to monitor the efficacy of fire zone protection.

3.7 Building Services

Electrical services were upgraded 10 years ago with little consideration of the services master planning, nor the original Utzon building planning and servicing concepts.

An automation project is in hand (for example, converting to C-BUS networks) that will address lighting control issues and strengthen the now much increased stage lighting and related automation systems throughout the building.

3.8 Security

A new security system has been installed that controls access to and monitors usage of the SOH facilities.

3.9 Asset Strategy

Over the last 2 years the Facilities Portfolio has established a number of standards for particularly building services systems (where most maintenance and associated works occur).

3.10 Current Services Status

A number of key concerns are evident at SOH:

- the building structure is complex, and building service systems - already the major cost of ongoing maintenance - are undergoing technology change, with new computer based services becoming increasingly important.
- the current “documentation” of the facility is comprised of several independent systems, some overlapping and is inadequate to service current and future services required
- the building has reached a milestone age in terms of the condition and maintainability of key public areas and service systems, functionality of spaces and longer term strategic management.
- many business functions such as space or event management require up-to-date information of the facility that are currently inadequately delivered, expensive and time consuming to update and deliver to customers.
- major building upgrades are being planned that will put considerable strain on existing Facilities Portfolio services, and their capacity to manage them effectively

4. Building Information Models (BIM)

An important consideration in the context of the current dimensionally inaccurate 2D CAD data, and significant upgrade projects planned for SOH over the next 5-10 years is the use of an integrated model of the building – other wise called a Building Information Model to support in a comprehensive manner all the asset and facility management operations required by SOH.

4.1 A Definition of BIM

Simply put a building information model (BIM) is a database specifically for built facilities.

BIM is an integrated digital description of a building and its site comprising objects, described by accurate 3D geometry, with attributes that define the detail description of the building part or element, and relationships to other objects e.g. this duct *is-located-in* storey three of the building named Block B.

BIM is called a *rich* model because all objects in it have properties and relationships, and based on this useful information can be derived by simulations or calculations using the model data. An example is the ability to perform automated code checking to confirm egress, fire ratings etc. or a thermal load calculation.

The principal difference between BIM and 2D CAD is that the latter describes a building by independent 2D views (drawings), e.g. plans, sections and elevations. Editing one of these views requires that all other views must be checked and updated if necessary, a clumsy and error prone process that is one of the major causes of poor documentation today. In addition, the data in these 2D drawings are graphical entities only, e.g. line, arc circle, etc. in contrast to the intelligent semantic of BIM models, where objects are defined in the terms of building parts and systems eg spaces, walls[2], beams, piles etc.

4.2 Generic Attributes of BIM

The key generic attributes are:

- *robust geometry* - objects are described by faithful and accurate geometry, that is measurable
- *comprehensive and extensible object properties* that expand the meaning of the object - any object in the model has some pre-defined properties or the IFC specification allows for any number of user or project specific properties according to a common format. Objects thus can be richly described e.g. a manufacturers' product code, or cost, or date of last service etc.
- *semantic richness* - the model provides for many types of relationships that can be accessed for analysis and simulation e.g. is-contained-in, is-related-to, is-part-of etc.
- *integrated information* - the model holds all information in a single repository ensuring consistency, accuracy and accessibility of data
- *life cycle support* - the model definition supports data over the complete facility life cycle from conception to demolition, extending our current over-emphasis

[2] Technically a wall in an IFC model is called *ifcWall* etc.

on design and construction phase. For example client requirements data such as room areas or environmental performance can be compared with as-designed, as-built or as-performing data, a vital function for asset and facility management.

4.3 BIM Benefits

The key benefit of BIM is its accurate geometrical representation of the parts of a building in an integrated data environment.

Related benefits are:

- *Faster and more effective processes* – information is more easily shared, can be value-added and reused
- *Better design* – building proposals can be rigorously analysed, simulations can be performed quickly and performance benchmarked enabling improved and innovative solutions
- *Controlled whole life costs and environmental data* - environmental performance is predictable, life-cycle costs are understood
- *Better production quality* – documentation output is flexible and exploits automation
- *Automated assembly* - digital product data can be exploited in downstream processes & manufacturing
- *Better customer service* – proposals are understood through accurate visualisation
- *Life-cycle data* – requirements, design, construction and operational information can be utilised in facility management
- *Integration of planning and implementation processe*s – government, industry and manufacturers have a common data protocol
- *More effective and competitive industry*

4.4 Interoperability or Building Data Sharing

Interoperability is defined as the *seamless sharing of building data between multiple applications (or disciplines) over any or all life cycle phases of a building* development project. Although BIM may be considered as an independent concept, in practice, the business benefits of BIM are dependent on the shared utilisation and value-added creation of integrated model data.

To access model data therefore requires an *information protocol*, and although several vendors have their own proprietary database formats, the only open global standard is that published by the International Alliance for Interoperability (IAI) called IFC.

4.5 The IFC Protocol

The IAI is a worldwide alliance of organisations in the construction industry - Architecture, Engineering, Construction and Facility Management (AEC/FM) - comprising 12 international chapters, from 21 countries with representation by over 550 businesses from private industry and government.

The IAI's stimulus in developing the IFC protocol was the recognition that the greatest problem in the construction industry today is the management of information about the built environment. Although every other business sector has embraced IT and adopted industry specific standards, the Construction Industry - indeed worldwide – has stuck to its trade based roots and dependence on drawings, with a continuing record of poor quality, low investment value and poor financial rewards.

4.6 Data Sharing with BIM

The mission of the IAI is to integrate the AEC/FM industry by specifying a universal language that improves communication, productivity, delivery time, cost, and quality throughout the design, construction, operation and maintenance life cycle of buildings.

The focus on life-cycle has been a key aspect, as the current industry practice does not facilitate the efficient transfer of requirements, design and as-built construction data for the increasingly critical phases of operations and strategic asset & facility management.

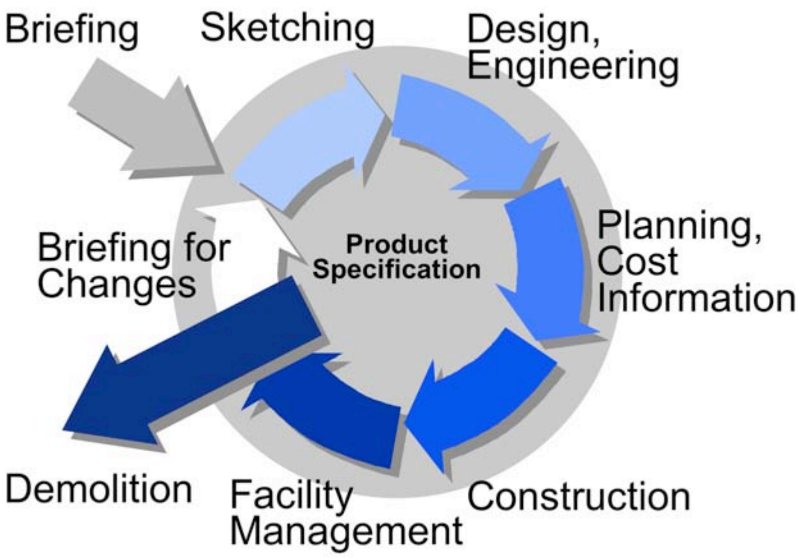

Figure 2: Information Lifecycle, Arto Kiviniemi, VTT

The focus on life-cycle has been a key aspect, as the current industry practice does not facilitate the efficient transfer of requirements, design and as-built construction data for the increasingly critical phases of operations and strategic asset & facility management.

In the discussion which follows we emphasise that building models and open interoperability are necessary complements of each other. Without the IFC sharing standard, data cannot be accessed in an industry open format; similarly, use of IFC requires integrated model data and cannot work with 2D drawings.

4.7 Initial Developments

The standard, which has undergone several releases since the first commercially supported version IFC 1.5.1 in 1999, commenced – principally in northern Europe - with the major (so called *upstream*) CAD vendors implementing IFC support. This development demonstrated the feasibility of modelling the building geometry (or shell) and as such largely covered the architectural layout of a building.

4.8 Building as a System

From 2000-2003 the model was extended in two important respects: first definition of a stable platform within the standard, a core to encourage more vendors to support the protocol by ensuring the initial investment software development had a secure future. The second, more directly important for users, was support for engineering systems, structures – concrete, steel timber and pre-cast, and building services – HVAC, electrical, hydraulic, fire etc.

The combination of these developments now underpinned a wide number of typical business case processes, and thus attained a level of functional maturity enabling IFC to be adopted as an ISO standard (ISO/PAS 16739) in 2002, the first such comprehensive information standard for building in the world.

The recent extension of the model for GIS data has provided a reliable link between the building and the planning professions, enabling public authorities and government to manage and innovate services based on comprehensive, reliable information databases of buildings and their land/urban context - the Built Environment.

5. Industry Take-up

5.1 Finland

World leader in model based construction services

With the steady improvement of IFC came several new vendors - *downstream* applications for building and engineering services, allowing in Finland a definitive case study, under the sponsorship of Government through its Technology agency Tekes, pro-actively promoting model based construction services. The Helsinki University of Technology Auditorium project originally designed by Alvar Aalto, was undertaken by the owner of University facilities in Finland, Senate Properties to test the benefits of IFC based collaboration. The project was independently reviewed by the Centre for Integrated Facilities Engineering at Stanford, US. Their **PM4D Final Report**, (CIFE Technical Report 143 - see http://www.stanford.edu/group/4D/download/c1.html) documented the pros and cons of this BIM/IFC based project. Senate Properties' ambitions were not completely met, but the CIFE evaluation clearly showed that substantial benefits were achieved where IFC collaboration was successful; the report not only identified positive issues, it also examined why communication failed and how this might be improved. The assessment covers the priorities of the many participants and from the client's perspective the project made enormous progress in showing the benefits based on this new process and data sharing protocol.

Importantly the review confirmed the strategic benefits of this approach for industry.

Auli Karjalainen, Customer Manager at Senate Properties confirmed the organization's continuing commitment to model based facility development. (see http://www.stanford.edu/group/CIFE/FinSoftwareDay/Presentations/SenateFSDatCIFE.pdf?siteID=2): "Working as a team with Product Models in Virtual Reality will result in a better quality of process and product, better solutions of spaces for the client, opportunities to change functions in the future, better opportunities for making decisions during the process, especially in early phases of projects, client commitment and an effective process through networking"

Since 2002 many pilots and projects have been undertaken in Finland, Sweden, Norway, Germany, France, Singapore, UK and Australia, which have demonstrated the capability of the IFC model to represent data and processes with in the AEC/FM domain accurately and efficiently.

5.2 Singapore

Innovation in building code checking

The Building Construction Authority of Singapore – a member of the IAI – had been developing an automated code checking service since the early 90's with limited success using then current 2D drawing CAD software, and realized in 2000 that IFC offered a definitive technology for the proposed system. In 2003 it released its first operational automated code checker accessed through a single web portal and newly integrated administration of some 13 agencies responsible for building assessment and regulatory approval. The ePlanCheck system uses an expert system, based on an IFC model server, to interpret and check a building proposal submitted to it in IFC file format. The Singapore development system uses the new IFC 2x2 functionality and following certification of a supporting CAD system (ArchiCAD) and the ePlanCheck system itself, has released it to the Singapore industry for use.

ePlanCheck has generated a lot of international attention – the automation, reuse of intelligent data, and time saving alone showed dramatic new potential; the IFC model data not only could be used as a better environment for multi-disciplinary design, it also was shared for building assessment and could act as reference data for local government and other government agency uses. Notably the rich data could be used for asset and facility management if during the construction process as-built information was updated in the model.

5.3 Norway

Leveraging ePlanCheck through GIS

The Norwegian government visited Singapore in late 2003, and were impressed by the system. An MOU was established between the two countries allowing Norway to use ePlanCheck technology and the national building agency Statsbygg undertook the development of a Development Approval System - Byggsøk. While this shared a similar structure as the Singapore system, it needed land and planning information that was not yet supported by the IFC standard. Accordingly Norway, with comprehensive geographic information systems in place, lead a project to bridge this gap and in May 2005 another significant turning point for IFC and BIM was the release of a new version of the IFC standard that supports integration with GIS data.

Norway accomplished this in just over 13 months, demonstration of the rapidly improving base technology, expanding application support and widening knowledge of BIM and IFC. Implementation by the government agencies in Singapore and Norway with automated building regulation checking and development zoning approval systems respectively are underpinning innovative and much more efficiently delivered services by local & national government agencies responsible for the certification and management of built development.

5.4 USA

General Services Administration (GSA) mandates IFC for capital works approval

The North American Chapter of the IAI is a founding partner and has played a dominant role in supporting the IFC effort.

Statistics released by the US Department of Commerce show that in four decades, from 1964 to 2004, productivity in the construction industry has actually declined while in all other non-agricultural industries productivity is up 30%. An August 2004 Report by NIST[3] entitled "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry" quantified the annual costs to the capital facilities industry, of $15.8 billion which represents between 1-2% of the industry's revenue.

'Starting in October[4], when fiscal year 2006 begins, all AEC firms dealing with the General Services Administration will have to include a building information model (BIM) as part of their work proposal. Stephen Hagan, who heads GSA's Project Knowledge Center… threw out his challenge to the construction industry by saying that his organization is not looking for new a technology, but rather for an efficient way to solve a serious business problem. GSA has $12 billion in active projects. "Too many are not on time and not on budget," …

The real value of BIM, says contractor Jim Bedrick, director of systems integration at Webcor Builders, is the ability to collaborate between architect, builder and major subcontractors, leading to better value for the owner. He sees the BIM model as having long term implications for the owner's ability to operate and maintain the facility after the construction hand-off. Detailed modeling gives the owner easy access to critical building information.

Hagan would like to see the AEC community create added value for the owner by specifically building a BIM model just for operations and maintenance purposes.

… Martin Fischer, director of Stanford University's Center for Integrated Facility Engineering (CIFE) confirmed with hard data that utilizing 3D and 4D modeling at the appropriate early stages in the design and construction process results in significant building efficiencies and cost savings. For example, he cited in one project, "usable square footage increased 20% in the same building footprint because of better modeling'.

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[3] See NIST website http://www.bfrl.nist.gov/oae/publications/gcrs/04867.pdf

[4] See Engineering News Record article
http://enr.com/print.asp?REF=http://enr.com/news/informationtech/archives/050121.asp

6. Facility Management Support in IFC

The capacity for whole facility life cycle management has been a central concept in the IFC model specification (see Figure 2 above). The core model is a rich description of the building elements and engineering systems that provides an *integrated* description for a building. This feature together with its geometry (for calculation and visualisation), relationships and property capabilities underpins its use as an asset and facility management database.

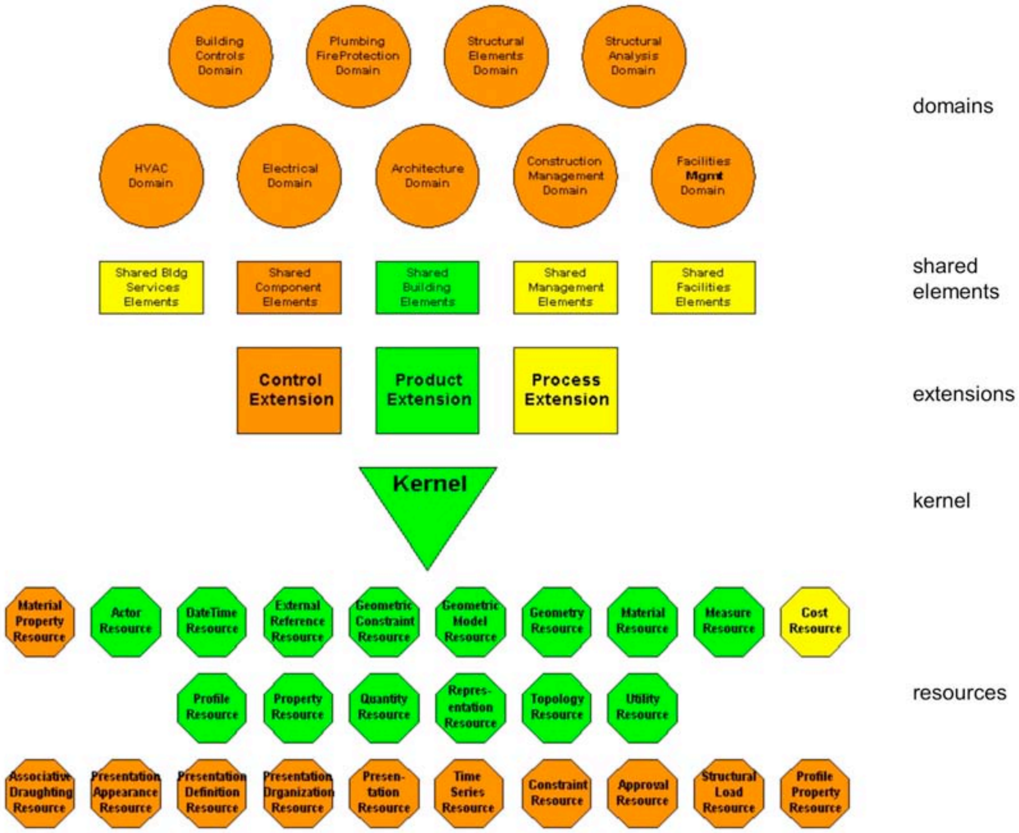

Figure 3: IFC 2x series Model, Model Support Group, IAI International

However, the model from its first release has supported many other concepts needed for operational asset or facility management. Referring to Figure 3 above, the model is represented as follows:

- *resources* – fundamental concepts, generally taken from the STEP standard[5]
- *the kernel* – concepts used globally in the model
- *extensions* – specialization of resources needed uniquely for AEC/FM domains
- *shared elements* – common concepts used by domains

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[5] ISO 10303 STEP - **Standard for the Exchange of Product Data** is the parent standard of IFC, and encompasses support for the manufacturing sectors of Shipbuilding, Process Plant, Offshore and Building & Construction,

- *domains* – functionally independent views (or disciplines) of the AEC/FM model

The model specialises data for use in various domains eg Architecture, HVAC and for our purposes Facilities Management.

6.1 Some Key Concepts of the IFC Model[6]

Before describing in detail the more specific concepts that may apply to Facility and Asset Management a number of general IFC concepts (called "kernel" in the IFC specification) will help to set the context.

IfcProject The undertaking of some design, engineering, construction, or maintenance activities leading towards a product. The project establishes the context for information to be exchanged or shared, and it may represent a construction project but does not have to.

IfcActor defines all actors or human agents involved in a project during its full life cycle. It facilitates the use of person and organization definitions in the resource part of the IFC object model.

IfcProduct Any object, or any aid to define, organize and annotate an object, that relates to a geometric or spatial context. Subtypes of *IfcProduct* usually hold a shape representation and a local placement within the project structure.

This includes manufactured, supplied or created objects (referred to as elements) for incorporation into an AEC/FM project. This also includes objects that are created indirectly by other products, as spaces are defined by bounding elements.

In addition to physical products (covered by the subtype *IfcElement*) and spatial items (covered by the subtype *IfcSpatialStructureElement*) the *IfcProduct* also includes non-physical items, that relate to a geometric or spatial contexts, such as grid, port, annotation, structural actions, etc.

IfcProcess An action taking place in building construction with the intent of designing, costing, acquiring, constructing, or maintaining products or other and similar tasks or procedures. Processes are placed in sequence (including overlapping for parallel tasks) in time, the relationship *IfcRelSequence* it used to capture the predecessors and successors of the process. Processes can have resources assigned to it, this is handled by the relationship *IfcRelAssignsToProcess*.

IfcPropertyDefinition defines the generalization of all characteristics (i.e. a grouping of individual properties), that may be assigned to objects. Property definitions can be property set definitions, or type objects.

IfcRelationship The abstract generalization of all objectified relationships in IFC. Objectified relationships are the preferred way to handle relationships among objects.

IfcRelAssociatesDocument This objectified relationship is used to assign a document reference or a more detailed document information to objects. A single document reference can be applied to multiple objects.

IfcRelAssociatesLibrary This objectified relationship (*IfcRelAssociatesLibrary*)

[6] The following specification is extracted from the IFC Model Specification (see http://www.iai-international.org/Model/files/20040721_IfcR2x2_Add1_html_distribution.zip)

handles the assignment of a library item (items of the select *IfcLibrarySelect*) to objects (subtypes of *IfcObject*).

The relationship is used to assign a library reference or a more detailed link to a library information to objects, property sets or types. A single library reference can be applied to multiple items.

IfcControl is the abstract generalization of all concepts that control or constrain products or processes in general. It can be seen as a specification, regulation, cost schedule or other requirement applied to a product or process whose requirements and provisions must be fulfilled. Controls are assigned to products, processes, or other objects by using the *IfcRelAssignsToControl* relationship.

EXAMPLE: Controls are space brief, cost schedules, orders, work plan, etc.

IfcResource contains the information needed to represent the costs, schedule, and other impacts from the use of a thing in a process. It is not intended to use *IfcResource* to model the general properties of the things themselves, while an optional linkage from *IfcResource* to the things to be used can be specified (i.e. the relationship from subtypes of *IfcResource* to *IfcProduct* through the *IfcRelAssignsToResource* relationship).

For more examples of IFC element entities used in the description of SOH, see the BIMSS Report

6.2 IfcSharedFacilitiesElements

The IfcSharedFacilitiesElements Schema defines basic concepts in the facilities management (FM) domain. This schema, along with *IfcProcessExtension, IfcSharedMgmtElements* and *IfcFacilitiesMgmtDomain*, provide a set of models that can be used by applications needing shared information concerning facilities management related issues.

The IfcSharedFacilitiesElements schema supports ideas including:

- Furniture.
- Grouping of elements of system furniture into individual furniture items.
- Asset identification.
- Inventory of objects (including asset, furniture and space objects within separate inventories).

Model entities within the IfcSharedFacilitiesElements domain are:

IfcActionRequest is a request for an action to fulfill a need.

IfcCondition determines the state or condition of an element at a particular point in time

IfcConditionCriterion is a particular measured or assessed criterion that contributes to the overall condition of an artifact.

IfcEquipmentStandard is a standard for equipment allocation that can be assigned to persons within an organization.

IfcFurnitureStandard is a standard for furniture allocation that can be assigned to persons within an organization.

IfcMove is an activity that moves people, groups within an organization or complete organizations together with their associated furniture and equipment from one place to another. The objects to be moved, normally people, equipment, and furniture, are assigned by the *IfcRelAssignsToProcess* relationship.

IfcOrderAction is the point at which requests for work are received and processed within an organization.

IfcPermit A document that allows permission to carry out actions in places and on artifacts where security or other access restrictions apply.

6.3 IfcFacilitiesMgmtDomain

The *IfcFacilitiesMgmtDomain* Schema defines basic concepts in the facilities management (FM) domain.

The *IfcFacilitiesMgmtDomain* schema forms part of the Domain Layer of the IFC Model. It extends the ideas concerning facilities management outlined in the *IfcSharedFacilitiesElements* schema and management in general outlined in the *IfcSharedMgmtElements* schema. The objective is to capture information that supports specific business processes that are wholly within the domain of interest of the Facilities Manager. The aim is to provide support for information exchange and sharing within computer aided facilities management and computer aided maintenance management applications. The model extent will not support some of the more detailed ideas found in these applications.

The following are within the scope of this part of the specifications:

- Managing the movement of people and their associated equipment from one place to another. All types of move are considered to be within scope ranging from moving a single person from one office to another to the movement of complete organizations between locations.
- The assignment of facilities management standards according to roles played by actors within an organization. Assignment of standards is limited to space, furniture and equipment.
- Capturing information concerning the condition of components and assets both for subjective and objective assessment of condition.
- Recording the assignment of permits for access and carrying out work.
- Capturing requests for action to be carried out and the assignment of work orders to fulfill the needs expressed by requests.

The following are outside of the scope of this part of the specifications:

- Work interactions between actors and between space programs.
- Moving or identifying the movement of or identifying the need for (as a result of moving) electrical or telecommunications services or connection points or the need for new electrical or telecommunications equipment as a result of the move.
- Facilities management standards other than space, furniture and equipment.

Model entities within the IfcFacilitiesMgmtDomain domain are:

IfcAsset is a uniquely identifiable grouping of elements acting as a single entity that has a financial value

IfcFurnitureType defines a particular type of item of furniture such as a table, desk, chair, filing cabinet etc.

IfcInventory is a list of items within an enterprise

IfcOccupant is a type of actor that defines the form of occupancy of a property.

IfcRelOccupiesSpaces is a relationship class that further constrains the parent relationship *IfcRelAssignsToActor* to a relationship between occupants (*IfcOccupant*) and either a space (*IfcSpace*), a collection of spaces (*IfcZone*), a building storey (*IfcBuildingStorey*), or a building (*IfcBuilding*).

IfcServiceLife is the period of time that an artifact (typically a product or asset) will last.

IfcServiceLifeFactor captures the various factors that impact upon the expected service life of an artifact.

IfcSystemFurnitureElementType defines a particular type of component or element of systems or modular furniture.

6.4 IfcSharedMgmtElements

The *IfcSharedMgmtElements* schema defines basic concepts that are common to management throughout the various stages of the building lifecycle. The primary classes in the schema are all subtypes of *IfcControl* and act to manage or regulate the conduct of the project in some way. This schema, along with *IfcProcessExtension* and *IfcConstructionMgmtDomain*, provide a set of models that can be used by applications needing to share information concerning management related issues.

The objective of the IfcSharedMgmtElements schema is to capture information that supports the ordering of work and components, the development of cost schedules and the association of environmental impact information. The aim is to provide support for exchange and sharing of minimal information concerning the subjects in scope; the extent of the model will not support the more detailed ideas found in more specialized management applications.

The following are within the scope of this part of the specifications::

- Principal types of order that may be used in the project and whose details need to be captured for the project including purchase orders, change orders and work orders.
- Schedules of costs.
- Association of cost and environmental impact of information to specific objects as required.

The following are outside of the scope of this part of the specifications:

- Transaction details that may be supported by or support electronic commerce.

Model entities within the IfcSharedMgmtElements domain are:

IfcCostItem describes a cost or financial value together with descriptive information that describes its context in a form that enables it to be used within a cost schedule.

IfcCostSchedule brings together instances of *IfcCostItem* either for the purpose of identifying purely cost information as in an estimate for constructions costs, bill of quantities etc. or for including cost information within another presentation form such as an order (of whatever type)

IfcProjectOrder sets common properties for project orders issued in a construction or facilities management project.

IfcProjectOrderRecord records information in sequence about the incidence of each order that is connected with one or a set of objects.

IfcRelAssignsToProjectOrder is a relationship class that captures the incidence of a project order for a set of objects and whose occurrences can be recorded within a project record in sequence as a series of events.

IfcRelAssociatesAppliedValue enables the association of an instance of IfcAppliedValue with one or more instances of *IfcObject*.

IfcRelSchedulesCostItems is a subtype of *IfcRelAssignsToControl* that enables one or many instances of *IfcCostItem* to be assigned to an instance of *IfcCostSchedule*.

6.5 IfcProcessExtension

The *IfcProcessExtension* schema provides the primary information that expands one of the key ideas of the IFC Model. This is the idea of 'process' which captures ideas about the planning and scheduling of work and the tasks and procedures required for its completion. It is important to understand that process information can be expressed by classes in exactly the same way as product information. A process can also have state and identity, the state being determined by the values of various attributes of the processes.

The *IfcProcessExtension* schema extends the primary idea of the *IfcProcess* outlined in the *IfcKernel* schema. The objective of the *IfcProcessExtension* schema is to capture information that supports the planning and scheduling of work and the procedures and resources required to carry out work. The aim is to provide support for information exchange and sharing within commonly used scheduling applications; the extent of the model will not support the more detailed ideas found in more specialized scheduling applications.

The following are within the scope of this part of the specifications:

- definition of work plans including the tasks that are included within the plan and identification of the resources required by the plan,
- definition of work schedules together with the elements that make up the schedule, the time constraints and durations applicable to the elements,
- identification of work tasks included in plans and schedules,
- identification of procedures that are considered to not consume time in their accomplishment,
- identification of the relationship between a process and the resources that are consumed by the process,
- allocation of resources to work plans, work schedules and work tasks.

Model entities within the *IfcProcessExtension* domain are:

IfcProcedure is an identifiable step to be taken within a process that is considered to occur over zero or a non-measurable period of time.

IfcRelAssignsTasks is a relationship class that assigns an *IfcTask* to an *IfcWorkControl*. The assignment is further qualified by attaching an *IfcScheduleTimeControl* to the assignment to give the time constraints of the work task, when assigned to a work plan or schedule.

IfcScheduleTimeControl captures the time-related information about a process including the different types (i.e. actual, or scheduled) of starting and ending times, duration, float times, etc.

IfcTask is an identifiable unit of work to be carried out independently of any other units of work in a construction project.

IfcWorkControl is an abstract supertype which captures information that is common to both *IfcWorkPlan* and *IfcWorkSchedule*

IfcWorkPlan represents work plans in a construction or a facilities management project.

IfcWorkSchedule represents a task schedule in a work plan, which in turn can contain a set of schedules for different purposes.

6.6 Strategic Asset Management

The features above demonstrate the comprehensive model functions for asset and facility planning.

In summary BIM/IFC supports:

- Integrated facilities management
- Common operational picture for current and strategic planning
- Visual decision-making
- Open, universal standards
- Automated code & performance checks
- Total ownership cost model
- Energy simulations, performance
- Physical security (CBR, sick building)
- Intelligent 4D simulations
- Construction management

7. FM/AM IFC Compliant Software

A number of IFC based applications exist internationally (and one locally) for AM/FM applications.

7.1 Vizelia, FR

This product has been written from scratch based on the IFC standard, initially for one of France's largest insurance companies AXA, for local and international offices' facility management. Recently the product has been installed for the Municipality of Luxembourg.

The application has strong space management functions.

[more details to follow]

7.2 Ryhti, FI

FM decision making processes require efficient management of information. Up to date information is essential both for strategic planning and leadership. It is also crucial for the management of facility services, for ensuring building functionality and for the monitoring of building performance.

To ensure this, a tool that enables measurement, monitoring and analyzing of trends and following up targets is needed. When necessary, the tool must provide the possibility to drill into details.

RYHTI FM information management system

Systematic information is needed on all levels of operations, by top-level management, regional managers and service personnel as well as by service providers. The information must be easy to read and essential to the reader. In addition, the presentation of the information has to be adjustable to possible changes in operations and business models.

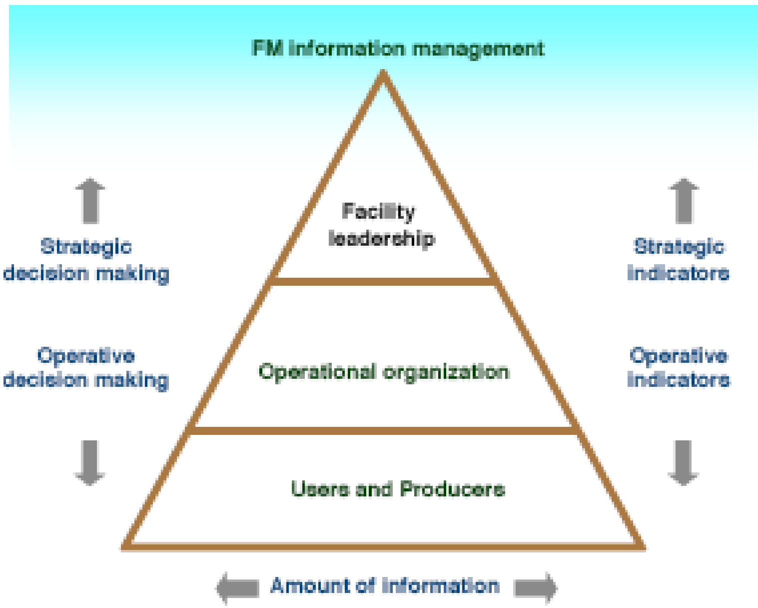

Figure 4a: RYHTI FM Interface

To meet these needs, Granlund has developed the RYHTI software for the management of buildings or entire building stocks. The RYHTI software has been developed in cooperation with leading real estate owners and maintenance organizations.

The RYHTI system is based on modules, enabling each organization to choose the appropriate package for its needs and purposes. The package, which can easily be expanded at a later stage, fulfils the needs of the entire organization and helps to allocate resources for the essential.

RYHTI is the tool to enable the organization to develop operation models and to process data into information. Correct information is the basis for making the right decisions and reaching better results.

Data management

All modules of the RYHTI software run on a common database, which creates the basis for an efficient management of information. The database contains information on the facilities, technical systems, equipment, people and documents. Due to the open structure of the database, the system can easily be adjusted to the individual needs of different organizations.

Functions according to needs

The RYHTI software covers the technical management of facilities according to customer requirements. Because of its modular structure, the software can be expanded with changing needs.

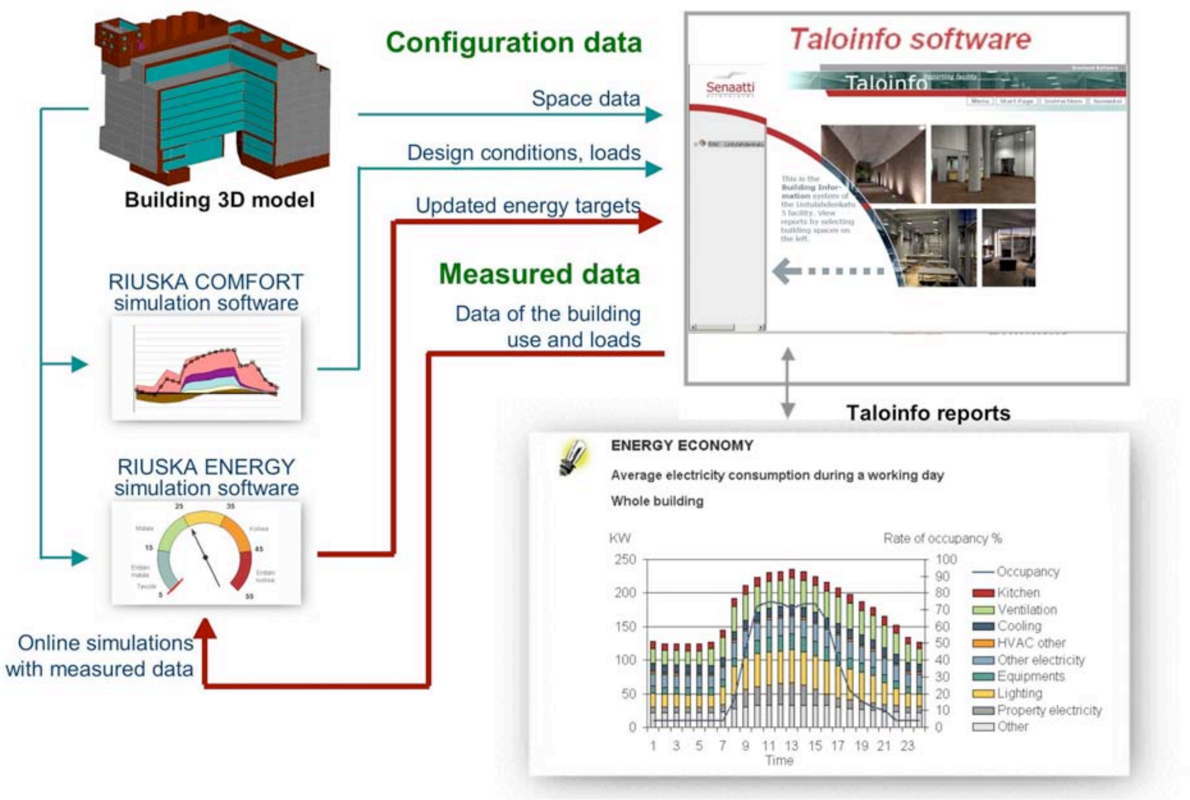

Figure 4b: Use of Product Models in Taloinfo System for Senate Properties, Finland, Olaf Granlund.

The following modules are available for the technical management of facilities:

- Maintenance, maintenance, planning and monitoring.
- Help Desk, request management and monitoring.
- LTP (Long Term Planning), planning and monitoring of long term maintenance and refurbishment.
- Contract, management of service contracts.
- Consumption, monitoring and reporting of energy and water consumption.
- Document, management and archiving of facility related drawings and other documents.
- Report, generation of reports fitted to the needs of the organization.

User roles and operational environment

Most RYHTI functions are compatible both in PC OS and Web environments. The Web application makes the use of the information system efficient and easy. Access to the information in the system can be defined to fit the tasks and roles of each user.

Ryhti is used by over 300 clients, including Finland's Senate Properties, Nokia & Pfizer UK.

7.3 Rambyg, DK

This application has been developed in Denmark, by one of the country's largest multi-disciplinary engineering practices Rambøll. Their primary clients are Estate owners (councils etc).

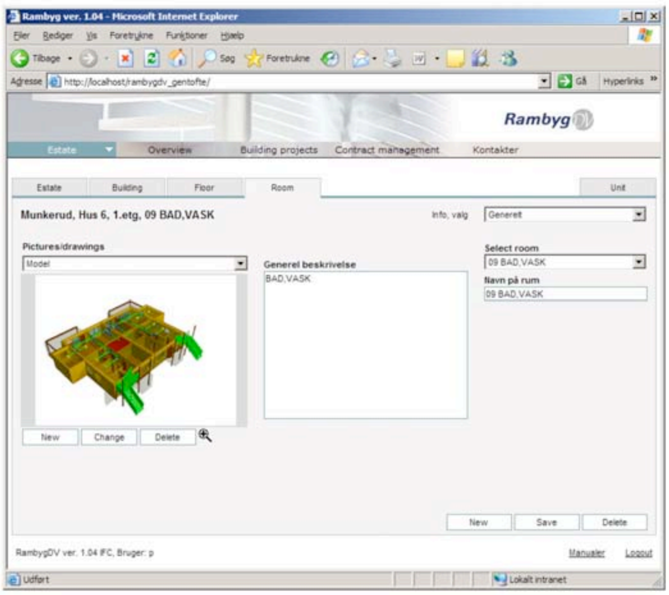

Figure 5: Rambyg FM Interface

Rambyg is a system for operation and maintenance of buildings. It is meant to be used during the lifetime of a building. The system is web-based – all data is in one place and access to all data from any place with an internet connection. All the different actors use the system directly. Data is put into the system close to the source and those who need data get it directly from the system.

The system is a standard system which has been sold for 4 years

The import of IFC-files is a prototype, converting a traditional relational database and 2D documents solution. IFC compatibility was recently added using a Japanese model server tool IMSvr. This was a very rapid development which has provided a new way for accessibility to rich data.

[mode details to follow]

7.4 ActiveFacility, AU

A Queensland based firm has developed an IFC server solution implemented in an Oracle database. ActiveFacility has created a new way of managing building data. This standard model stores, updates and provides ready access to the massive amount of information that relates to a building.

ActiveFacility's services and software systems are built on the ISO - endorsed International Foundation Classes standards and are progressive tools for managing building information throughout the lifecycle of a building.

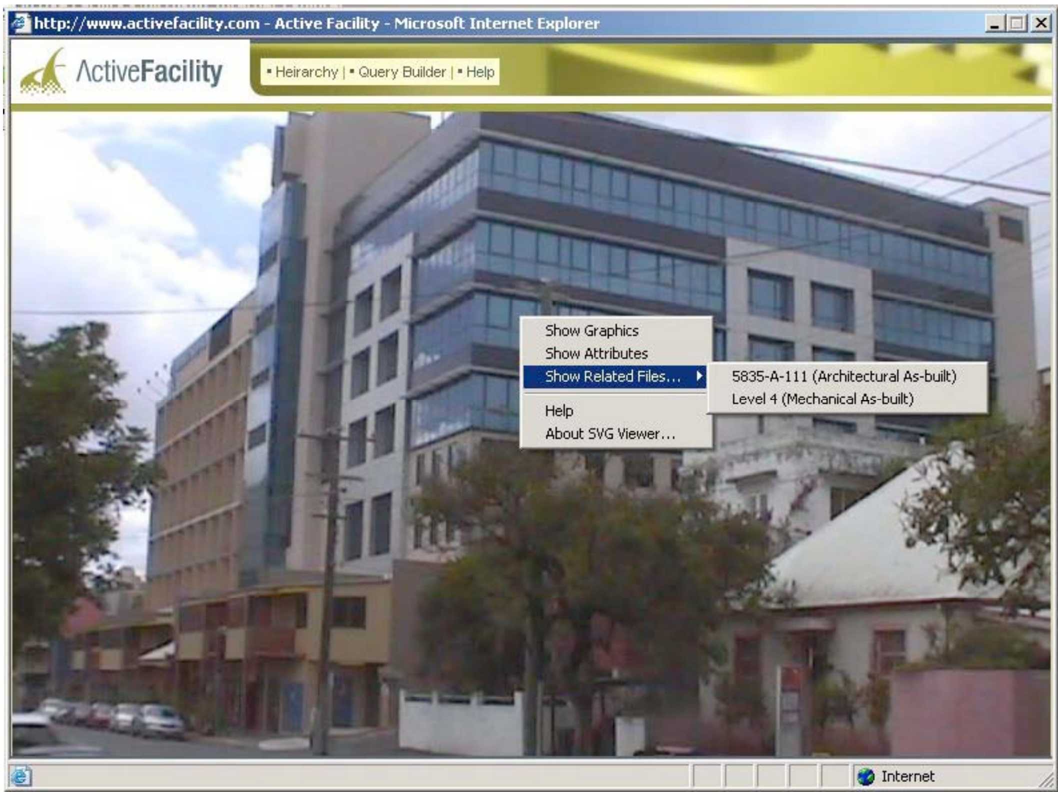

Figure 6: ActiveFacility System

Key features of the product[7] are:

- Creating an industry standard building model that encompasses all the information (architectural, mechanical, electrical, etc.) for an existing building.
- Making the unified building model accessible through the Internet so the

[7] ActiveFacility White Paper, 2 November 2004

information can be shared, analysed, queried and updated.

- Integrating the building model with other existing operational systems so all systems are continuously up-to-date.

A typical business issue: How do you answer everyday questions being asked of you, about your facility? Some typical examples could include:

- Where does this wire go?
- What is connected to the wire?
- Who will be affected if I cut this wire?
- What is the area of a certain flooring material used throughout the complex of buildings?
- What services run through the ceiling space over a particular room?

These questions, while superficially trivial are, in reality, complex queries that can span multiple documents or drawings with a low degree of confidence that the source information is accurate, current, or available. Industry research suggests that up to 80% of a Facility Manager's time is spent finding information about the buildings they are managing. So how can a system be developed to assist in the management of this data, provide access to the data, and develop tools and processes to keep the data up to date?

ActiveFacility's mission is to provide solutions that answer these questions.

With a complete set of documentation and data, the ActiveFacility team begins the process of building a Unified Building Model. This is a manual process that consists of identifying building objects in the document sets and constructing a complete set of data about that object. Tools allow definition of users, reporting etc

ActiveFacility supports Business Processes and workflows

The system is currently being used for Hospital asset and facility management.

8. Server Developments – the SABLE Project[8]

Sable - Simple Access to the Building Lifecycle Exchange – aims to replace file based data exchange by speeding up the use of Model Servers in the building industry. The SABLE project is being managed in Finland by EuroSTEP and is supported by the IAI, BLIS, the Finnish Government and a group of international software client groups and vendors.

It proposes to facilitate this through the creation of an abstraction of the data model defining *AEC Simple Interfaces (APIs)* to the data model instead of using it directly.

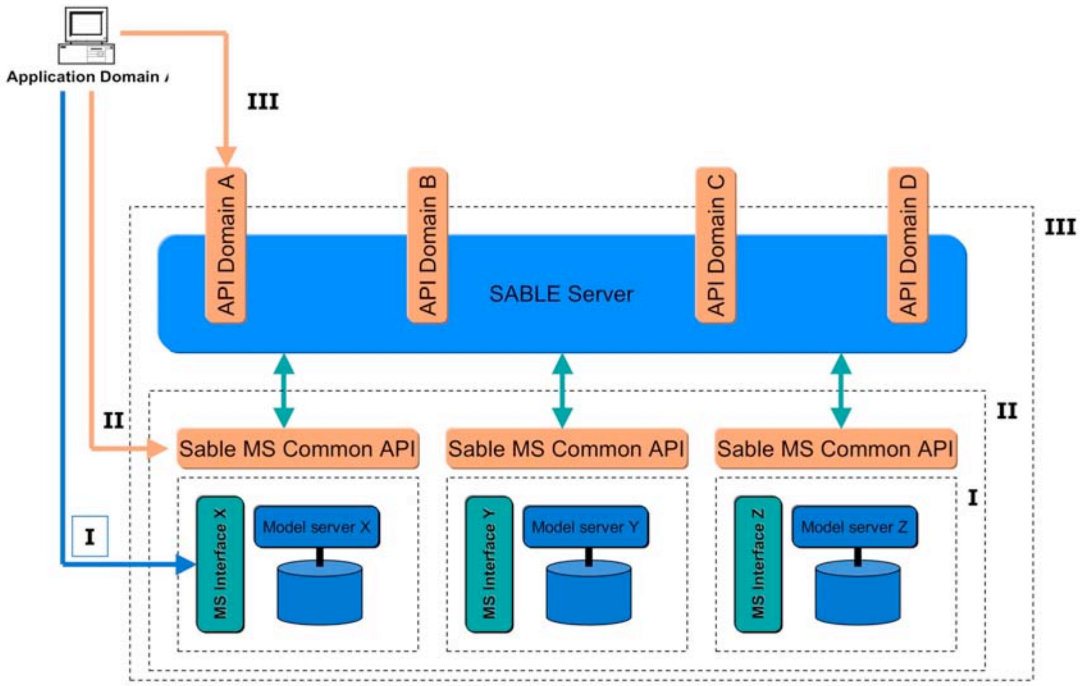

Figure 7: SABLE Model Server API Architecture, P Houbaux, EuroSTEP, Finland

This server approach

- Hides the complexity of the IFC data model by providing direct access to the needed data
- Minimises the dependency on the IFC Model version to allow the AEC application vendors to make their implementation compatible with future releases of the IFC model
- Proposes a unified and standard way to access model servers by unifying both the partial model exchange format and the interface for developers.

The SABLE interfaces are currently under development; three levels of implementation are possible: through the API domain API, the SABLE Common MS API or direct to the Model Server interface. These are likely to become available during 2006 and further.

[8] Simple Access to the Building Lifecycle Exchange (see http://www.blis-project.org/~sable)

An example of the evolving FM API development is described in detail in **Appendix B: SABLE FMIM API**

The advantage of this work is that a Facility Management API is being specified which will greatly assist Australian and other developers develop more quickly IFC compliance and exploit the benefits of the BIM integrated data repository.

9. International FM Projects – Ifc-mBomb[9]

***Note**: This description of the project is taken from the* Life-Cycle Data for Buildings: Opportunities of the IFC Model Based Operation and Maintenance *report, IAI UK, April 2005*

This project, funded by the UK Department of Trade and Industry, was carried out in the UK, completing in late 2004 and publishing its full results in 2005. The project leader was Taylor Woodrow, one of Britain's largest construction companies with a considerable portfolio of asset management and members of the IAI UK Chapter.

Ifc-mBomb's starting premise was this: "The efficient operation and facilities management of a building relies on accurate, high- quality information about the building itself. In practice, this transition is often stuttering and disjointed. Instead of a seamless reuse of the data, there is a manual re-inputting... The weakest information interfaces involve building services and facilities management. All in all, there is scope for error and omission, leading to problems in the operation and maintenance of the building later in its life cycle.

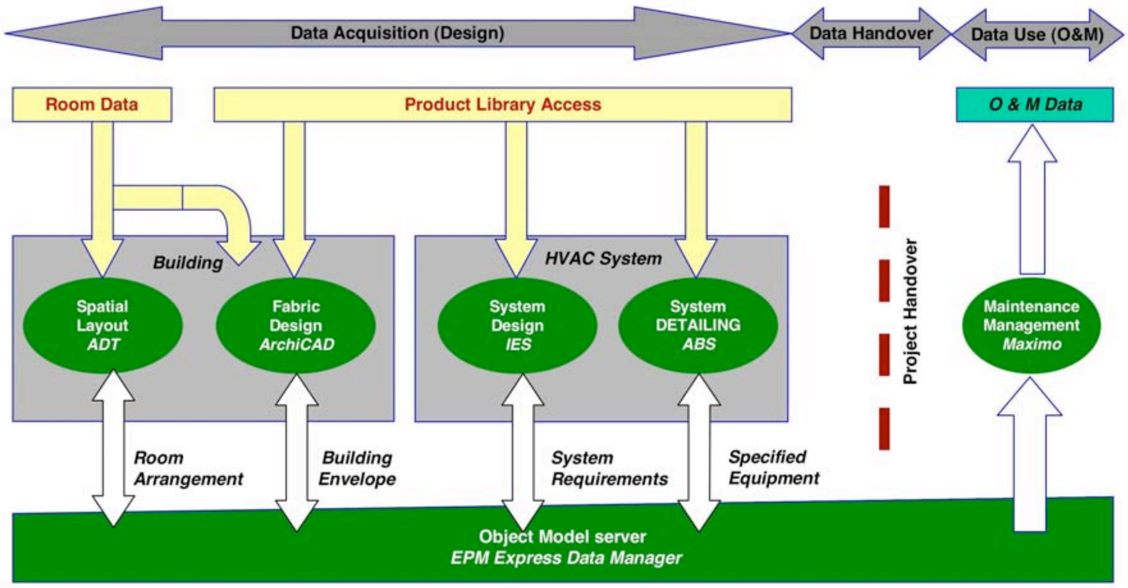

Figure 8: Ifc-mBomb Project concept, D Leonard & J Stephens, Taylor Woodrow, UK.

An end-user scenario was proposed at the start of the project. The aim was:

[9] see http://cig.bre.co.uk/iai_uk/iai_projects/ifc-mbomb/

- To take room data sheet information created by the client and architect and to populate a facilities management system with the room requirements data
- To add information to the building model as the design team developed the building design. The scenario focused on the design and detailing of the building services required for the auditorium, which was situated in the centre of the building and spanned two storeys
- To perform iterations to the building services design and detailing using a number of software applications sharing the same common building model
- To generate O&M manual information from the building model.

The project clearly demonstrated that using IFC model exchanges afforded more opportunities for end-users to select their preferred software application and still be able to exchange semantically rich data between systems. In many cases in the scenario, the choice of software used to create the building model was not important – as long as it was certified to support the IFC2x specification.

… more and more information could be added to the evolving IFC model as the building design progressed. This was achieved by using the EPM Technology EXPRESS Data ManagerTM – software that enabled complete IFC models to be imported and exported...

Information was truly reused through the design, construction and FM phases of the project's life-cycle, as outlined below by a number of examples:

- Occupancy and temperature levels were used by energy analysis software
- Room numbers used all applications to identify spaces and their locations
- Heating and cooling requirements from the energy analysis application were used by the ductwork detailing software to size the ductwork components and fittings
- The building element materials and thicknesses were directly reused from the architectural building model by the energy analysis application
- Room requirements data sheet information was available in the FM system as first created early in the design stage
- Manufacturers' product data and recommendations were obtained from electronic catalogues and added to the model when elements were upgraded from generic to specific products
- Hazard and safety information was related to specific instances during design and included (in red) in the O&M documents.

…Another benefit of the project was the opportunity for process change. Concurrent engineering and collaborative working were made possible – and easier – thanks to the Ifc-mBomb approach".

The Ifc-mBomb project provides reliable evidence of the technical practicality and operational benefits that BIM based FM can achieve.

10. Integrated FM Systems

10.1 Integrated Information

Several high-level processes have been identified that could benefit from standardized Building Information Models:

- maintenance processes using engineering data
- business processes using scheduling, venue access, security data
- benchmarking processes using building performance data

Linking this data together can support these processes even further. For example:

- Quickly find the responsible person/contract when an element fails.
- Retrieve all objects (walls, doors, etc) scoring on the BPI below x which have had a major maintenance
- Retrieve all history of cleaning scores of objects before and after a new cleaning contract for comparison
- List the location of assets and their performances including maintenance history
- Query vacated spaces and their Building Fabric Index scores
- Simulate and visualise the effect of taking a service out of commission
- The integration of (heterogenous) information sources supports the alignment of different processes. For example space planning and maintenance operations can benefit from integrated planning.

10.2 An Overview of an Integrated System for SOH

Figure 9 represents an overview of a framework for an integrated FM system for the SOH.

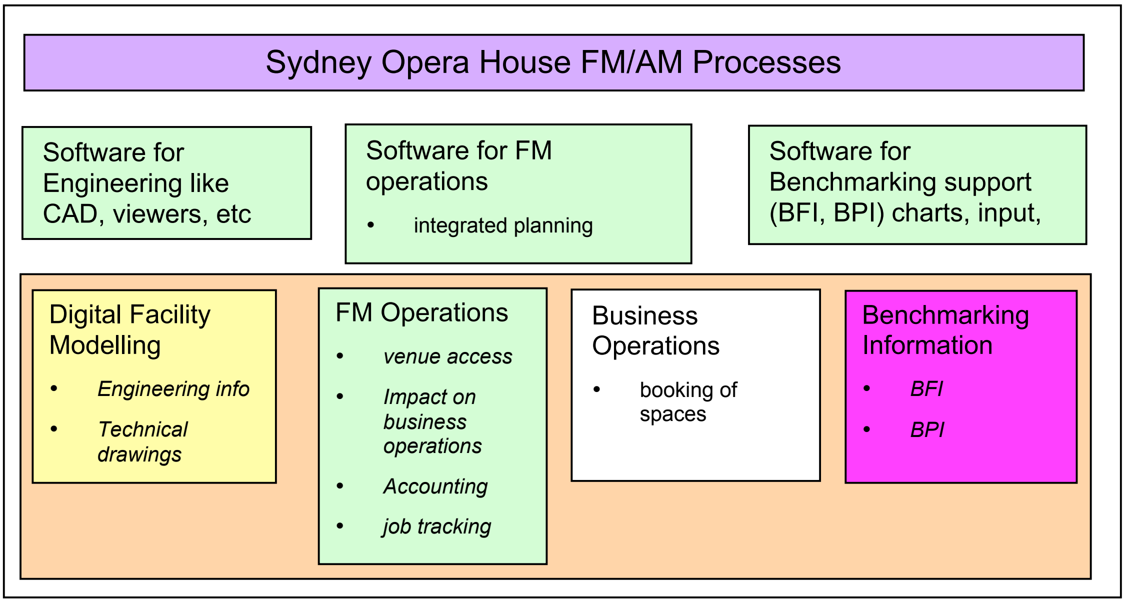

Figure 9: Digital facility modelling supporting SOH's FM/AM processes.

Obviously the information environment can be extended by many other sources of information such as OHS, etc. Eventually the system can become the body of knowledge for the Sydney Opera House storing best practices and implementing rules on top the information environment reducing risks and mistakes. For example the system could flag when certain spaces are performing under a certain threshold or make suggestions regarding maintenance planning.

10.3 Showcase

The showcase demonstrates and tests the potential of Digital Facility Models for the FM/AM industry.

10.3.1 SOH specific information

The integrated FM system needs to deal with SOH specific information such as SOH building decomposition and specific information such as BFI, BPI, etc.

Level 1 Building and Site

Level 2 Storey Settings

Level 3 Location zone

Level 4 Functional Space

Level 5 Room Type

Level 6 Room

Figure 10: The hierachy for decomposing the SOH.

The following screenshot demonstrates the usage of a Building Information Model which incorporates a part of the SOH decomposition. In addition the objects in the BIM have properties such as BFI and BPI.

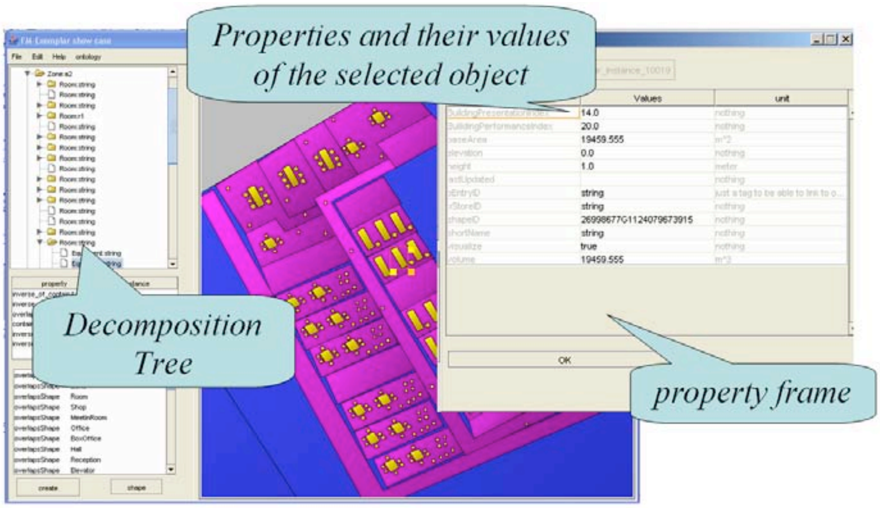

Figure 11: Objects such as building, storey, zone, room, chair are organised in a tree similarly as SOH building organisation structure. All objects have properties containing specific information such as BPI and BFI values. The objects, properties and their relation form the framework for the building model.Visual Reporting

The results of queries with colour coding techniques can be used to present the information using the building geometry. For example results of queries such as retrieving all objects with a certain performance index can be visualised (figure 10).

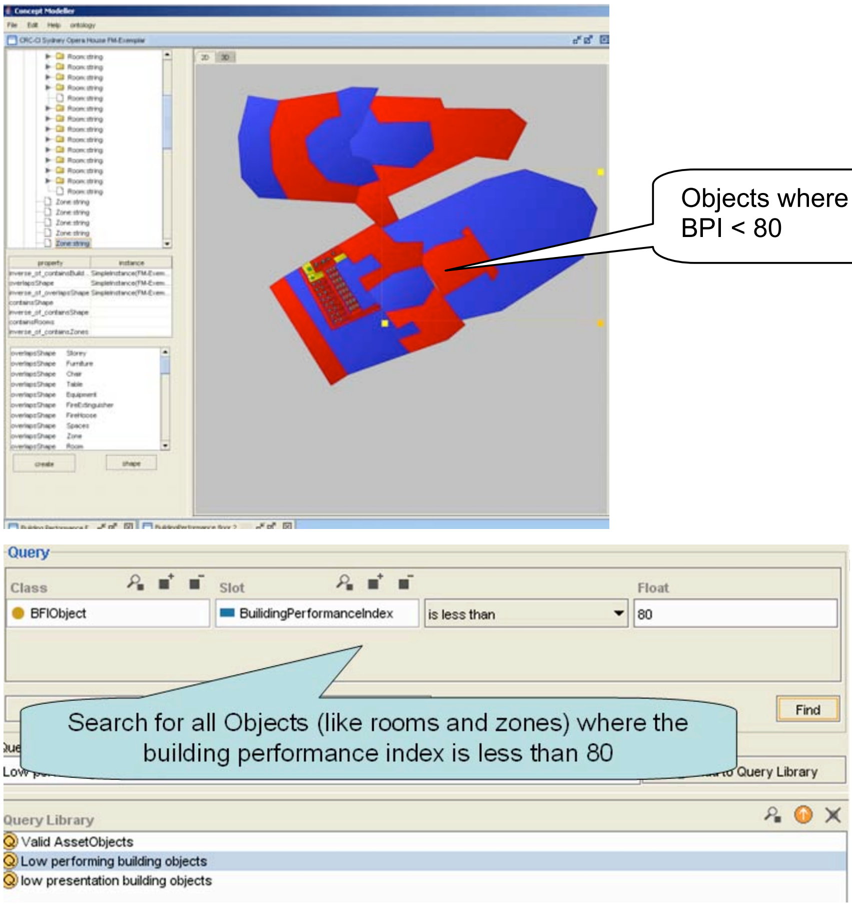

Figure 12: Visualising results of queries

The following screenshot shows an example where all the zone scores have been colour coded.

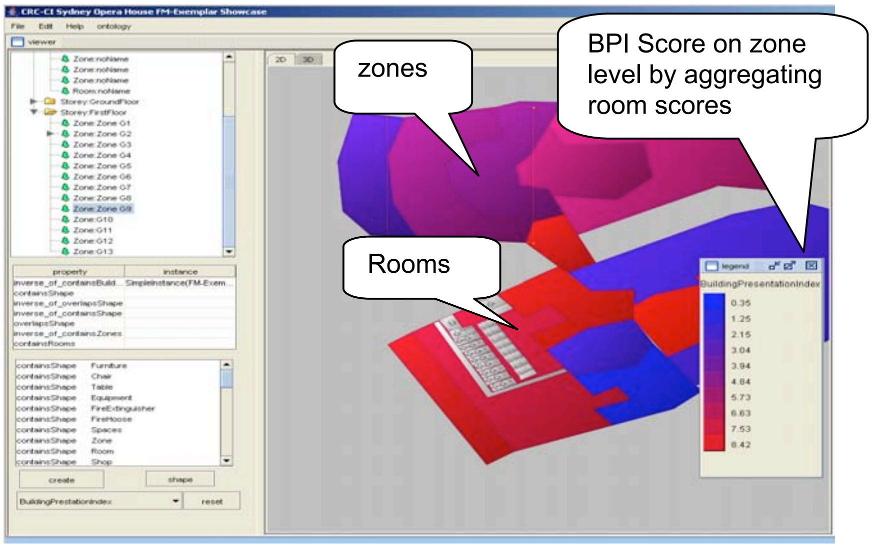

Figure 13: An example of how to present BPI and BFI more graphically by color coded indices

10.3.2 Adding Intelligence

Rules can be created working as an added layer of business intelligence using the raw, yet comprehensive data of the integrated database. For example BPI and BFI scores can be calculated automatically for zones. This can be done by aggregating the scores of objects 'in' the zone.

Other types of rules can help assess what will happen when for example a certain service is failing. The following example shows what happens when power is cut in one of the rooms. The system automatically shows the rooms affected by this action.

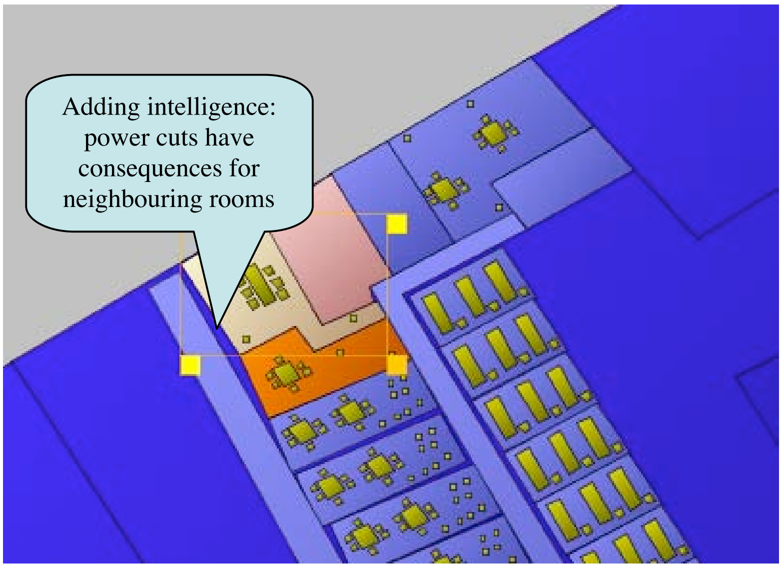

Figure 14: Computing and visualising the impact of taking a service out of commission

10.4 Interoperability

10.4.1 CAD interoperability

To build up a digital facility model, the use of IFC has been proposed. To demonstrate the feasibility of IFC based data, Arup's structural model has been exported from Bentley's Microstation in IFC format. This file has been imported in ArchiCAD without loss of data and then extended with rooms! From ArchiCAD a new expanded export in IFC format has been used in the showcase software used by CSIRO.

This modest, but informative, test has confirmed that a partial model of the House could be created. Where possible, this test model\ adopted the standards proposed in the draft BIM Standard Specification for SOH (see separate report). Structural, Architectural and Analysis applications were able to share and collaborate with the same model data.

To progress to a full model will involve further testing, elaboration of the specification resolution of technical issues. This is a substantial project but will significantly improve data quality and AM/FM functionality.

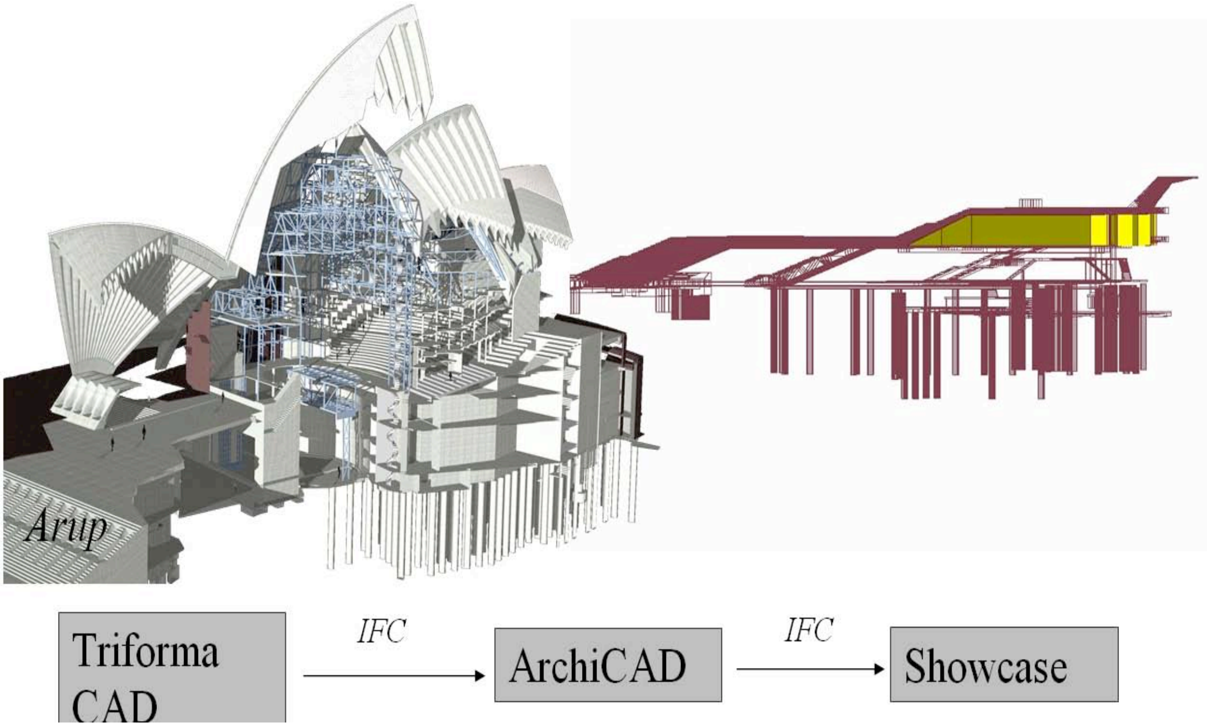

Figure 15: IFC interoperability between different software systems.

10.4.2 Extending the model with Benchmarking

Figure 16 is a simplified data model for storing and retrieving benchmarking data. The data model defines zones having several functional spaces. The functional spaces contain elements such as doors, walls, etc. Several elements are already available in the Digital Facility Model such as the elements, doors, walls, etc. Such a schema can easily be implemented in a relational database such as a SQL DB.

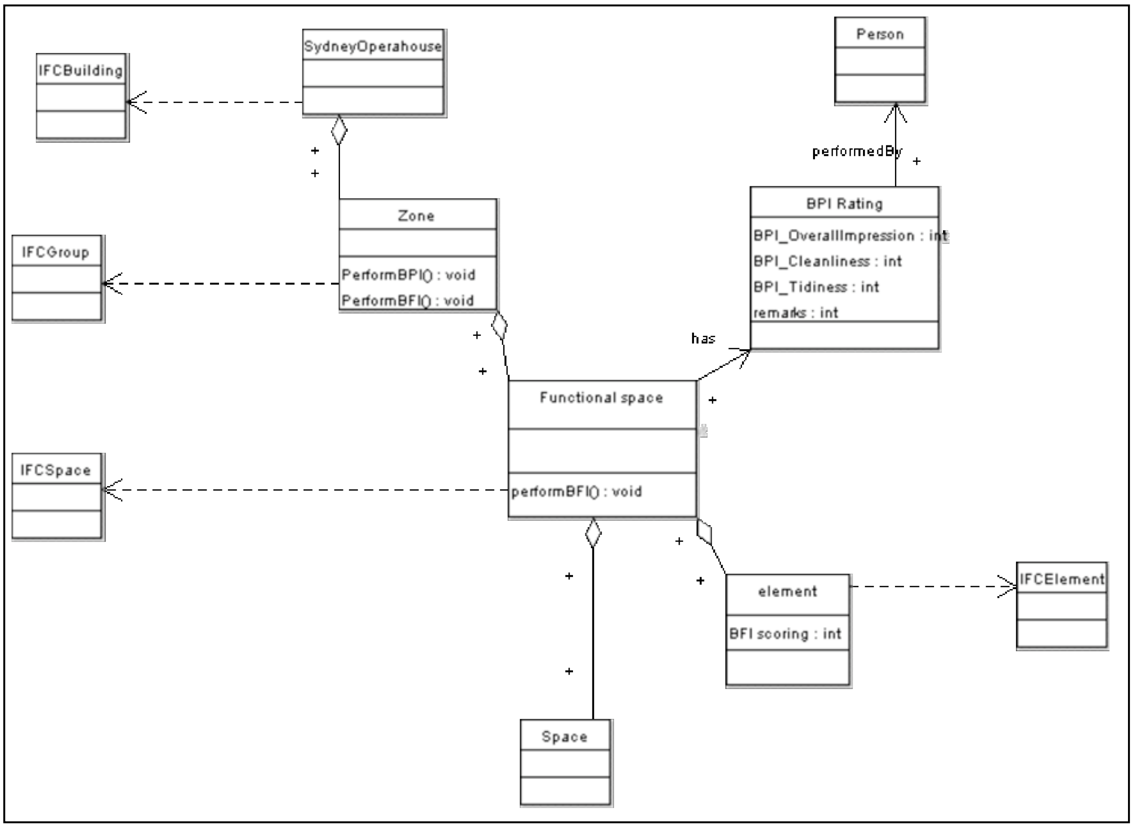

Figure 16: Simplified data-model for supporting benchmarking including relations to the IFC

This specific SOH data-model can be linked with a standardized building information model such as the IFC. For example functional Spaces can be linked with the IFC Space (figure 17).

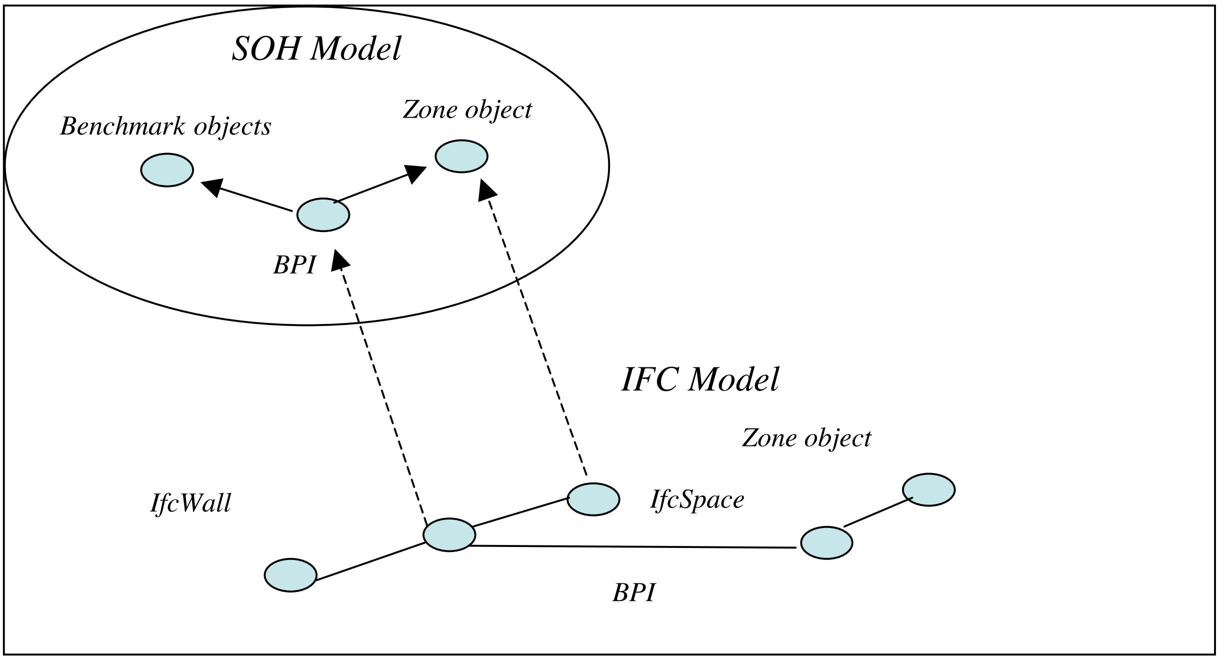

Figure 17: adding company specific information.

The result is an integrated model combining the IFC with a benchmarking data model. This approach has been implemented resulting in a system re-using IFC data extended with SOH specific functionality such as BPI history data, etc (figure 18).

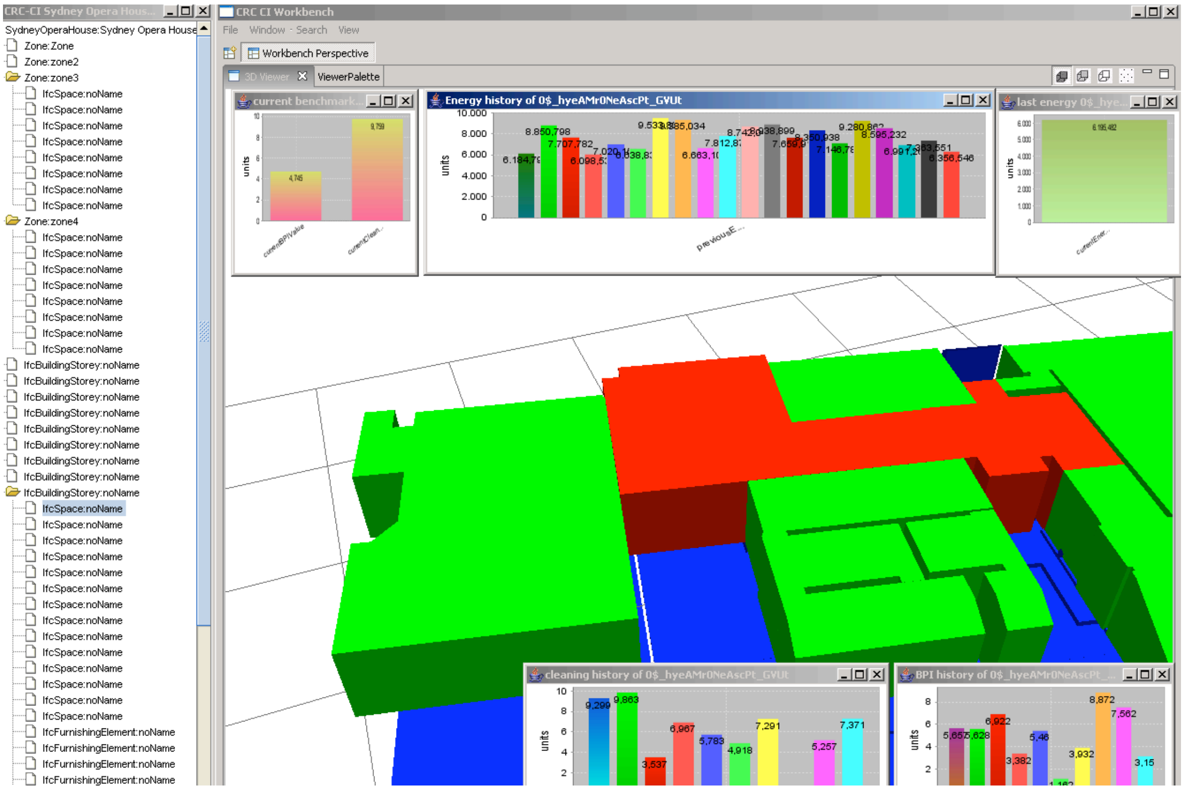

Figure 18: IFC based showcase extended by SOH benchmark model

This showcase demonstrates the re-use of the IFC model for Facility Management purposes and demonstrates the potential of extending the IFC with more organisation specific information.

10.5 Technical Recommendations

10.5.1 Centralised Approach

Temporarily setting aside existing tools and infrastructure, an ideal situation would be to have an integrated data model containing all relevant information for the Sydney Opera House for different departments (Figure 19). Such a data model would have a benchmarking module containing the necessary benchmarking data. All other necessary data would be re-used. The data would be reasonably maintainable. However the applications need to be compliant with this data model. It seems that extending the IFC data model could potentially be such a data model. In addition a heterogenous solution containing for example a SQL database and links to the IFC model is also feasible.

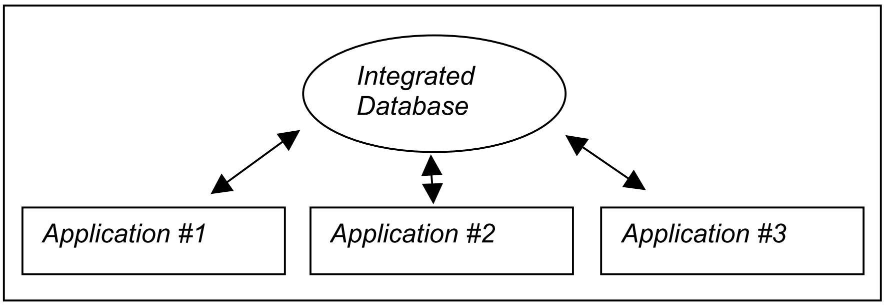

Figure 19: Integrated data model.

10.5.2 Decentralised Approach

Already several systems are installed such as 'MainPac' and space planning software. These software systems have their own database or data storing mechanism. Overlap of information can be present. This means that similar information resides in different databases resulting in redundancy. In order to keep all systems up-to-date changes in the data must be communicated to several other databases. Integration of these databases means that these relationships have to be determined and implemented (Figure 20). When many applications are available the amount of relationships can increase rapidly.

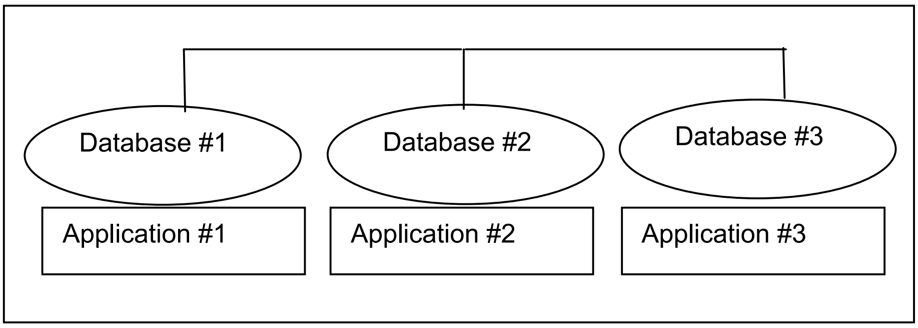

Figure 20: Decentralised approach.

The decentralised approach is also a feasible approach. Nowadays standardized communication languages are available. Querying over different systems and combining its information is possible. A simple interface could be the based around the unique ID of each element. For example a room planning calendar service could provide booking information based on a room ID (and a date). The maintenance calendar could do the same thing for maintenance operations. Location service could provide the location of an element by submitting its ID. Software applications can use these services to provide its users more information (Figure 21).

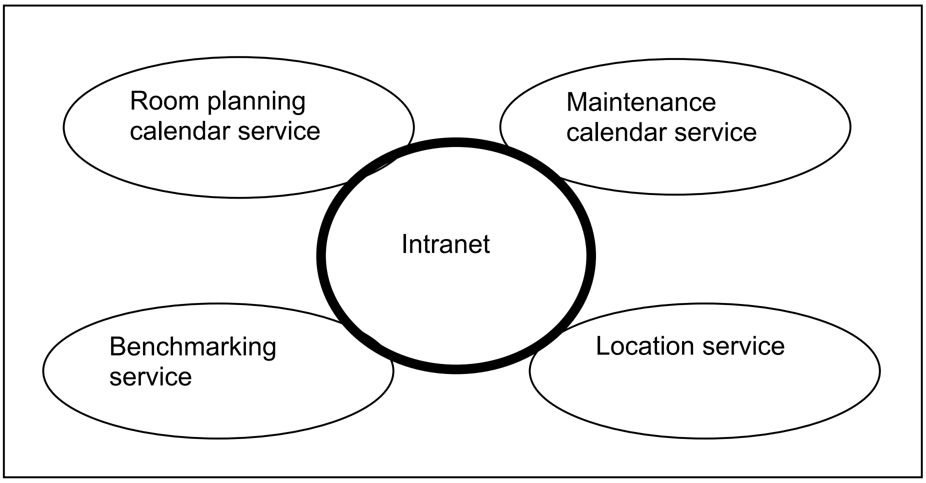

Figure 21: Potential Web services for the Sydney Opera House

An advantage of these web services approach is that the systems are loosely coupled. Updating a system or completely replacing one can be done without problems when the service is kept the same. In addition new services can join the intranet in order to deal with future extensions.

11. Summary

It is clear that a software environment for Facility Management can comprise a large scope in terms of size of data, number and types of users, and functions to be performed.

Introducing a complete, holistic environment at once is not very feasible for many obvious reasons. An evolving/growing software system is more likely where functionality is added progressively and/or more couplings with existing systems are established.

The IFC's can be recommended as standardized data exchange protocol assuring interoperability between different systems for now and in the future. This enables the SOH to gradually build up the building model without being locked in by a certain supplier (using a certain CAD system).

12. Key Findings

The project has established the following:

BIM *– building information modelling - is an appropriate and* ***potentially beneficial technology*** *for the storage of integrated building, maintenance and management data for SOH*

Based on the attributes of a BIM, several advantages can be envisioned:

- *Consistency* in the data. Data is accurate and multiple versions of the same data are eliminated.
- *Intelligence in the model*. For example *windows* are automatically related to walls and cannot be located otherwise. A *switchboard* is part of a logical network of circuits, is geometrically described and is located spatially in a room on a storey of the building. Changing the height of a wall automatically updates relationships, quantities , etc.
- *Multiple representations* such as 2D drawings, 3D views, bills of quantities, logical connections (a building services system schematic)
- *Source of information for intelligent programs*. For example several CAD packages offer sunlight analysis, acoustic performance, sustainability.
- *Intelligent queries* such as how many steel beams are in the model > 2 meters, etc or which fire-rated doors have a current compliance certificate?.

The ***IFC*** *– open building exchange standard – specification* ***provides comprehensive support for asset and facility management functions****, and offers new management, collaboration and procurement relationships based on sharing of intelligent building data.*

The major advantages of using an open standard are:

- The information can be read and manipulated by any compliant software;
- Reduced user “lock in” to proprietary solutions. Third party software can be the “best of breed” to suit the process and scope at hand;
- Standardised BIM solutions consider the wider implications of information exchange outside the scope of any particular vendor;
- The information can be archived as ASCII files for archival purposes.

Data quality can be enhanced as the now single source of users’ information has improved accuracy, correctness, currency, completeness and relevance.

SOH current building standards *have been successfully drafted for a BIM environment and are confidently expected to be fully developed when BIM is adopted operationally by SOH*

There have been remarkably few technical difficulties in converting the House’s existing conventions and standards to the new model based environment. This demonstrates that the IFC model represents world practice for building data representation and management.

SOH has already implemented data quality checks to improve reliability and synchronisation of data which is a good platform for further development

*Availability of **FM applications based on BIM** is in its infancy but focussed systems are already in operation internationally and show excellent prospects for implementation systems at SOH*

In addition to the generic benefits of standardised BIM described above, the following FM specific advantages can be expected from this new integrated facilities management environment:

Faster and more effective processes – information is more easily shared, can be value-added and reused;

The IFC specification allows for any number of *user or project specific properties* according to a common format. This is one area where proprietary BIM solutions may constrain users. In some proprietary systems it is very difficult for an ordinary user to add additional properties;

- *Controlled whole life costs and environmental data* – environmental performance, maintenance and investment is predictable, life-cycle costs can be analysed and understood;
- *Better customer service* – information can be accessed in multiple formats appropriate to each user ie seating plans are understood through accurate visualisation;
- *Common operational picture* for current and strategic planning – as model data is inter-related developing scenarios and their impacts (such as budgeting for major maintenance, assessing security or understanding dislocation during construction activity) can be understood more easily leading to better decision making;
- *Visual decision-making* – allows executives, management and lay users (particularly) to understand the nature and relationships of the facility, eg building services failures through graphic 3D or abstract views generated from the model, etc;
- *Total ownership cost model* – all aspects of the facility including building usage and operations are in a single integrated repository.

*Tests with partial BIM data – provided by several of SOH's current consultants – show that the creation of a **SOH complete model** is realistic, but subject to resolution of compliance and detailed functional support by participating software applications*

The showcase has demonstrated successfully that IFC based exchange is possible with several common BIM based applications through the creation of a new partial model of the building. Data exchanged has been geometrically accurate (the SOH building structure represents some of the most complex building elements) and supports rich information describing the types of objects, with their properties and relationships.

*A **Benchmarking System**, already in use for a Building Presentation Index (BPI) for example, can be derived from the BIM model; whilst there are several options in detail, an ideal situation would be to have an integrated data model containing all relevant information for the Sydney Opera House for various departments. Such a data model would have a benchmarking module containing the necessary benchmarking data. All other necessary data would be re-used. The data would be* *reasonably maintainable. However software applications need to be compliant with this data model.*

13. Recommendations

13.1 Recommendations for the Facility Management industry

Standardised Building Information Modelling as an integrated information source for Facility Management processes including business processes is feasible.

- IFC offers interoperability between CAD systems enabling re-use of building information
- The IFC model is standardised making the data more future proof
- Already commercial FM software systems are available using IFC data
- Other related software such as energy prediction models and on-site monitoring are available using IFC data
- The IFC model is extensible and can incorporate organisation specific requirements

It is recommended that:

1. ***the Facility Management industry adopt IFC for the sharing of asset and facility management information***
2. **the FMAA with related organisations evaluate this report with a view to adopting IFC as a national standard for the exchange of information in the Built Environment.**

13.2 Recommendations for the Sydney Opera House

In summary, this study has identified a technology solution that can be implemented at SOH. An immediate benefit would be a description of information flows in the process and provide options for organisational and technical solutions to improve process efficiency. It would form an important road map to identify a technical and organisational frame work for improvement.

It is recommended that:

3. ***SOH adopt standardised BIM for the support of asset and facility management functions and proceed with the development of an Implementation Plan***
4. ***SOH presents these findings toappropriate Government agencies and seeks evaluation of this report with a view to its adoption in NSW as the standard for the exchange of information in the Built Environment***

There are many factors about which this study team has no knowledge nor a brief to consider, in particular funding, current asset and facility planning and operations, capital improvements, committed work etc.

The recommendations below are thus aimed at providing a guide to the main steps needed to proceed with the conversion to a BIM based building information environment.

The key steps needed for the SOH to proceed to implementing BIM are outlined below:

- Form a BIM Implementation Committee to manage the process with representatives from all relevant internal & external parties, directed by SOH
- Develop a budget for a (staged) implementation of the model
- Collaborate with interested parties – reporting agencies, consultants, suppliers, users and the House technical team to determine the availability and acquisition of operational BIM software to support model creation and management
    - Evaluate CAD tools that can edit model data and possibly host integrated data
    - Review Model Server options
    - Evaluate hardware needs for the above
- Work with appropriate stakeholders to pilot BIM modelling and IFC exchange to certify they support, comply and can collaborate according to the new SOH standards and procurement procedures
    - Ratify the draft BIM standards, in particular with the key disciplines of architecture, structure and building services.
- Commence implementation in a sequence for example as follows:
    - Implement small discipline SOH partial sub-models
    - Audit the existing Opera Hall sub-model to see how it complies with the SOH BIMSS
    - Develop a plan to upgrade it, extend all the relevant discipline data and create a preliminary SOH partial master model.
    - Review technology capabilities (servers etc) to suit the project master model
    - Develop a plan for the completion of the master models
- Liaise and regularly report on the BIM implementation with NSW Government and industry as a model of future information management, collaborative processes and potential for innovation

In parallel

- Develop a FM implementation plan to convert to the new BIM environment
    - Specify and procure an application
    - Audit the current systems and develop a staged conversion
    - Implement of convert trail benchmarking data
- Work with external suppliers and contractors to develop procurement systems based on the SOH BIM model.

Appendix A: IFC Elements checked with Sydney Opera House Elements proposed for BPI and BFI

The following table will cross link IFC elements with the elements used for BPI and BFI. This will give an overview of which elements are already supported by international standardization of the IFC and which elements have to be defined as proprietary objects / properties.

SOH category Number	SOH name	IFC Name	SOH category Number	SOH name	IFC Name
000	Building General	IfcBuilding	2400	HVAC	
0100	Substructure		2500	Fire Safety	
0200	Structure		2600	Electrical Service	
0400	Stairs	IfcStair	2700	Communications	
0500	Roof	IfcRoof	3000	Catering	
0700	Window	IfcWindow	3300	Roads, Paving	
0800	Doors External	IfcDoor	3600	Landscaping	
0900	Partitions	IfcSpace	3700	Drainage:stormwater	
1000	Handrails, Barriers	IfcRailing	3800	Drainage:sewage	
1100	Doors:internal	IfcDoor	4600	signage	
1200	Wall finishes	IfcCovering	5000	Stage Machinery	
1300	Floor finishes	IfcCovering	5100	Stage Lighting	
1400	Ceiling finishes	IfcCovering	5200	Stage audio	
1500	Furnishings	ifcFurnishing Element	5300	Stage audio Visual	
1700	Sanitary Systems	IfcDistribution element	5600	Security	
1900	Water service	IfcDistribution element	6000	Workshops	
2000	Gas Service	IfcDistribution element	9100	Artwork	
2300	Central Plant				

ifcSystem/ *ifcGroup* for grouping various elements.

IfcProxy for objects such as Stage Machinery, etc.

Appendix B: SABLE FMIM API[10]

B.1 SABLE Domain Specific API Requirements: Inventory Management

Authors: Jiri Hietanen

Reference: SABLE-DAPI-FMIM

History: Document started 06.09.2004

Contents revised based on comments from PH (17.09.2004)

Reviewers: Patrick Houbaux (PH)

Introduction

This domain specific API is used for connecting alphanumeric inventory data to graphical, project specific design data. In this scenario the project specific graphical design data is accessed through the SABLE server, but the alphanumeric inventory data is stored in some other repository, typically an object library. The graphical design data itself is published and accessed through the SABLE design APIs, such as the architectural API, and not through this API. It is important to note, that an API is not equal to a software product. An inventory management application may provide functionality for creating and manipulating graphical design data, in which case it would implement both this API and the appropriate design APIs. (All geometry exchanged through the SABLE server is ultimately published and accessed through the SABLE geometry API)

The primary motivation for connecting alphanumerical inventory data to graphical design data is to make it easier to locate the inventory items. The secondary motivation is to provide a better user interface for managing the location of the inventory items. For example moving furniture from one space to another is often easier by drag-and-drop on a floor plan than using drop-down lists and other standard user interface components. The most important location information for inventory items is a space, i.e. inventory items can typically be assigned to a single space. However, there are also cases in which inventory items belong to more than one space, for example doors and piping. The spaces in turn may belong to different location structures, such as building storeys, wings, zones, tenants, functional categories etc. This API supports assigning inventory items to spaces and configuring spatial structures. This API does not support assigning individual inventory items to other locations than spaces, but each inventory item may belong to several spaces.

Inventory items have a standard type classification, which follows the IFC2x2 specification. This classification defines the type and an optional subtype for each inventory item.

[10] http://www.blis-project.org/~sable/subprojects/DAPI_FMIM_index.html

For example inventory items of the type "Electrical Appliance" have the following sub types:

.COMPUTER.

.DIRECTWATERHEATER.

.DISHWASHER.

.ELECTRICCOOKER.

.RADIANTHEATER.

.FACSIMILE.

.FREESTANDINGFAN.

.FREEZER.

.FRIDGE_FREEZER.

.HANDDRYER.

.INDIRECTWATERHEATER.

.MICROWAVE.

.PHOTOCOPIER.

.PRINTER.

.REFRIGERATOR.

.SCANNER.

.TELEPHONE.

.TV.

.VENDINGMACHINE.

.WASHINGMACHINE.

.WATERCOOLER.

In addition to this standard type classification each inventory item may have any number of freely defined classification references.

Inventory item instances may be with or without symbol. An inventory item with symbol has geometry and location in the SABLE repository, which means that the inventory item has to be published and accessed through one of the SABLE design APIs. Inventory items without symbol may be created through the Inventory Management API. For example a door created by an architectural application may be managed as an inventory item with symbol, but a office space may contain 'a list of' standard furniture, which is managed as inventory items without symbol. Inventory items, which are understood in the API to be without symbol, may have a 'library symbol' in the inventory management application. One alternative is to access such symbols as an external references.

Each inventory item may have attached properties. This API does not enumerate what those properties are; it just makes it possible to attach, detach and modify properties. The properties attached to the inventory items depend on the scenario in which the API is used. Sometimes it may be best to attach no properties at all to the inventory items and to keep all properties in the repository of the inventory management software. In other cases it may be best to store some data or the copy of some data on the SABLE server, e.g. when there is a need to share this data with other applications. Inventory item properties have a name, type and value. Individual properties may be grouped together as property sets

This API supports both instance properties and properties, which are shared between inventory items. It also supports type definitions, which are independent from any inventory item instances. Exchanging type definitions through the SABLE server is necessary e.g. when several inventory management applications access the same data. Type definitions may have properties for which the value is defined by the type (e.g. manufacturer) or by the instance (e.g. serial number).

Design data typically has a fixed structure, in which each space belongs to one building storey. In addition to this each space may belong to any number of groups. Each of these groups has a type and groups may be organized into tree structures. Other structures, e.g. graphs are not supported. This API does not enforce any rules about the groups, e.g. that each space would always belong to at least one group or that each space would occur only once in a given group tree. The enforcement of any such rules is the responsibility of the client applications.