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Sydney Opera House – FM Exemplar Project

Report Number: 2005-001-C-3

Open Specification for BIM: Sydney Opera House Case Study

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Executive Summary

The objective of this report was to use the Sydney Opera House as a case study of the application of Building Information Modelling (BIM). The Sydney opera House is a complex, large building with very irregular building configuration, that makes it a challenging test.

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

While some of these concerns are unique to the House, many will be common to larger commercial and institutional portfolios.

The work described here supported a complementary task which sought to identify if a building information model – an integrated building database – could be created, that would support asset & facility management functions (see **Sydney Opera House – FM Exemplar Project, Report Number: 2005-001-C-4 Building Information Modelling for FM at Sydney Opera House**), a business strategy that has been well demonstrated.

The development of the **BIMSS - Open Specification for BIM** has been surprisingly straightforward.

The lack of technical difficulties in converting the House's existing conventions and standards to the new model based environment can be related to three key factors:

- SOH Facilities Portfolio – the internal group responsible for asset and facility management - have already well established building and documentation policies in place. The setting and adherence to well thought out operational standards has been based on the need to create an environment that is understood by all users and that addresses the major business needs of the House.
- The second factor is the nature of the IFC Model Specification used to define the BIM protocol. The IFC standard is based on building practice and nomenclature, widely used in the construction industries across the globe. For example the nomenclature of building parts – eg ifcWall, corresponds to our normal terminology, but extends the traditional drawing environment currently used for design and documentation. This demonstrates that the international IFC model accurately represents local practice for building data representation and management.
- a BIM environment sets up opportunities for innovative processes that can exploit the rich data in the model and improve services and functions for the House: for example several high-level processes have been identified that could benefit from standardized Building Information Models such as maintenance processes using engineering data, business processes using scheduling, venue access, security data and benchmarking processes using building performance data. The new technology matches business needs for current and new services.

The adoption of IFC compliant applications opens the way forward for shared building model collaboration and new processes, a significant new focus of the BIM standards.

In summary, 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.

These BIM standards and their application to the Opera House are intended as a template for other organisations to adopt for the own procurement and facility management activities. Appendices provide an overview of the IFC Integrated Object Model and an understanding IFC Model Data.

SYDNEY
OPERA HOUSE

Open Standard Specification for BIM (BIMSS)

Consultative Document

[This is a working document, issued for discussion and subject to revision]

FM Exemplar Project

CRC for Construction Innovation

Sydney, May 2006

Final Version

Contents

1. Introduction

This document introduces new processes and technology to manage assets at the Sydney Opera House.

Before adopting these procedures, the SOH seeks feedback from consultants, suppliers and contractors and the Construction Industry in general.

1.1 Purpose of this Specification

This Specification defines the data standards applicable for integrated building model data for the Sydney Opera House Master Model.

1.2 Building Information Modelling

Building Information Modelling (BIM) is a new approach to describe and display the information required for the design, construction and operation of constructed facilities. It is able to bring together the different threads of information used in construction into a single operating environment thus reducing, and often eliminating, the need for the many different types of paper documents currently in use.

To use BIM effectively however, and for the benefits of its use to be realised, the quality of communication between the different participants in the construction process needs to be improved. If the information required is available when it is needed, and the quality of that information is appropriate, then the construction process can be improved.

For this to happen, there must be a common understanding of building processes and of the information that is needed for and that results from their execution.

The Industry Foundation Classes (IFC) provides a comprehensive reference to the totality of information within the life-cycle of a constructed facility. It has been created as an integrated whole in response to the identification of business needs expressed by the international building construction community.

1.3 SOH Facilities Office Mission

The objective of the SOH is to build up an accurate, reliable, and relevant integrated building model of the Sydney Opera House complex to support operational management, building and service system alterations and additions and asset and maintenance management.

This is proposed to be achieved by progressive incremental development of a master model, in accordance with operational, logistic and financial constraints.

1.4 SOH Master Model Data

Master model data shall only be sourced from SOH with approval of the Technical Information Coordinator (TIC) at Sydney Opera House. No consultant or supplier shall use data provided to another party.

> **Note**: Users must use a model (generally a partial model) sourced from SOH. This is **mandatory** to ensure ifcEntity GUIDs (unique identifiers) are synchronised with the master model.

Where new model data is required to be created, this specification shall be used to determine the ifcEntity type, naming conventions and property data required.

Standard property sets (PSET) are defined for the IFC model and shall be used where applicable and in accordance with this specification. Custom PSETs may be used with the approval of the SOH TIC.

Obtain the approval of the TIC before commencing work.

1.5 SOH Sub-models

The SOH master model is divided into a number of logical discipline specific sub models. A user of the SOH Master Model shall obtain from the SOH TIC a designation of their organisation's discipline and the organisation's authorised representative details (name and ID).

Discipline types are as follows:

Discipline	Identifier
Architecture	ARCH
Land Use	PLAN
Terrain	SURV
Cadastre	CADA
Utilities	UTIL
Structure	STRU
Mechanical	MECH
Electrical	ELEC
Communications	COMS
CAVS	CAVS
Security	SECU
Hydraulic	HYDR
Transportation	TRAN
Equipment	EQUI
Civil	CIVI
Roads	ROAD

If the contractor's role is not covered by the above Discipline types, obtain one from the SOH TIC.

Contractors shall identify their organisation's details and designated representative in their IFC exports as follows:

IfcPerson

IFC Attribute	Setting
Id	Contractor Identifier issued by SOH TIC
FamilyName	Family name of Contractor's representative
GivenName	Given name of Contractor's representative
MiddleName	OPTIONAL
PrefixTitles	OPTIONAL
SuffixTitles	OPTIONAL
Roles	Not applicable
Addresses	Not applicable

IfcOrganisation

IFC Attribute	Setting
Id	Discipline ID (as defined above) eg "MECH"
Name	Organisation name
Description	OPTIONAL
Roles	Not applicable

Addresses	OPTIONAL

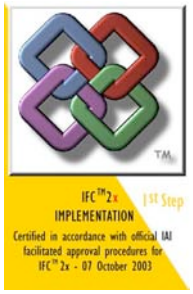
1.5 IFC Data Requirement

Building model data shall comply with IFC (ISO/PAS 16739), release 2x Platform and subsequent extensions (2x2 etc) format, and in accordance with this Specification. Earlier release versions may be used only with the approval of the SOH TIC and are generally not to be used.

File format may be in either Part 21 STEP physical file (SPF) ASCII (this is the default format); Part 28 XML (ifcXML) ASCII; or Part 22 SDAI STEP database access interface.

Note: Intending suppliers of IFC building model data should consult the SOH Facilities Office to confirm the most appropriate data sharing process.

1.6 IFC Certification



Software used to generate IFC data shall only be accepted from certified applications, that can demonstrate they have been tested and comply with the appropriate IFC functionality (see the logo opposite of the two part certification for the Singapore Code Checking project).

2. SOH IFC Model Setup

2.1 Scale

All models shall be in metric scale 1:1, with units in millimeters to 0 decimal places.

2.2 Coordinate System

The SOH Master Model is based on a geographical reference grid defined as the "Sydney Opera House Plane Grid", and is being incorporated on all survey information at Sydney Opera House. This grid is based on a permanent survey mark of PM 61988, which has a MGA Easting of 334800.324 and a MGA northing of 6252055.139. The bearing and distance of the principal azimuth between points PM 61988 and PM 59507 is 195°13'15" for a distance of 85.488 metres. The origin of levels is the State Survey Mark SSM 22994 which has a height of 4.458 on Australian Height Datum. The SOHPG is a local grid, rotated through an angle of 12°23'22" on the SOH local grid point P1-01(the commemoration plaque on the Forecourt Stairs). This angle has been determined from a survey of selected tiles on the western forecourt area and may not be indicative of the entire site.

The SOH has established a Survey Network (CCSN), comprising a set of Survey Marks throughout the site and buildings with reference to this datum.

All Model data shall be calibrated with these survey marks.

2.3 Layering

Layering in the IFC model has no explicit meaning and is a presentation attribute of model entities, which assists in applications to maintain layering definitions.

If layering is used then it shall conform to the **SOHT CADD Procedures Manual**, Revision 04.1, 1 October 2004.

2.4 IFC Project Data

See **Appendix B: Understanding IFC Model Data** for a description of the key IFC model entities**.**

2.4.1 Project

The project shall be represented by the *ifcProject* entity.

ifcProject

IFC Attribute	Setting
Name	SOH
Description	Sydney Opera House
Object type	Not applicable
Long name	Not applicable
Phase	TBC

Property Set usage is project and task dependent and shall be determined by SOH.

2.4.2 Site

The SOH facilities are spread over several sites; the main site is at Bennelong Point, and remote facilities at the Rocks (Arts Exchange), CBD (Young Street) and Leichardt (Depot)

The physical extent of the main site of the SOH Master Model is available from the SOH TIC.

A Site shall be represented by the *ifcSite* entity.

Note: Information about a site is represented by several disciplines: see section **3. The Site Model & GIS** for the specialist disciplines involved.

ifcSite

IFC Attribute	Setting
Name	Eg "Bennelong Point"
Description	Land title description
Object type	Not applicable

2.4.3 Buildings

The SOH Master Model is defined as the following building:

Sydney Opera House

The remote facility buildings are as follows:

Arts Exchange

Young Street Offices

Leichardt Depot

Buildings shall be represented by the *ifcBuilding* entity.

ifcBuilding

IFC Attribute	Setting
Name	eg "Sydney Opera House"
Description	Not applicable
Object type	Not applicable

Property Set usage is project and task dependent and shall be determined by SOH.

2.4.4 Storey Settings

All storeys in the Bennelong Point buildings shall be named in accordance with the following table:

Note: The original documentation of the SOH was in imperial units and the common name of the building storeys in use has been the height in *feet above sea level* eg "+03". This code is the formal reference for storeys.

All units shall be in mm.

Table A.1: Bennelong Point Building Storeys

Level Code	Feet above Sea Level	Level Name	Elevation in metres
SB	-008	Sub-basement	-2.4384
BA	+001	Basement	0.3048
LC	+003	Lower Concourse	0.9144
GR	+012	Ground / Forecourt	3.6576
GM	+021	Ground mezzanine	6.4008
L1	+030	First Level, Green Room, Box Office	9.1440
L2	+042	Second Level - Podiums & Bars	12.8016
L3	+051	Third Level - Mural & 'Caves' Level	15.5448
L4	+061	Fourth Level – 'Granite' Level	18.5928
AG	+070	Auditoria - Gallery, Loges & Boxes	21.3360
RC	+090	Auditoria - Reflected Ceiling Level +90	27.4320
AC	+100	Auditoria - Ceiling Level +100	30.4800
AU	+115	Auditoria - Ceiling Upper Level +115	35.0520
AA	+130	Auditoria - Ceiling Above Level +130	39.6240
AS	+140	Auditoria - Under Concrete Shells	42.6720

Note: Building Storey definitions for remote facilities shall be obtained from the SOH TIC.

ifcStorey

IFC Attribute	Setting
Name	*Feet above Sea Level* code as in Table A.1 above
Description	*LevelName* as in Table A.1 above (excepting levels VA and OH)
Object type	Not applicable
Long name	Not applicable
Complex type	Not applicable

Property Set usage is project and task dependent and shall be determined by SOH.

2.5 The Spatial Hierarchy

The SOH Master Model shall have spatial definitions comprising the following entities:

Location Zones

Functional Spaces

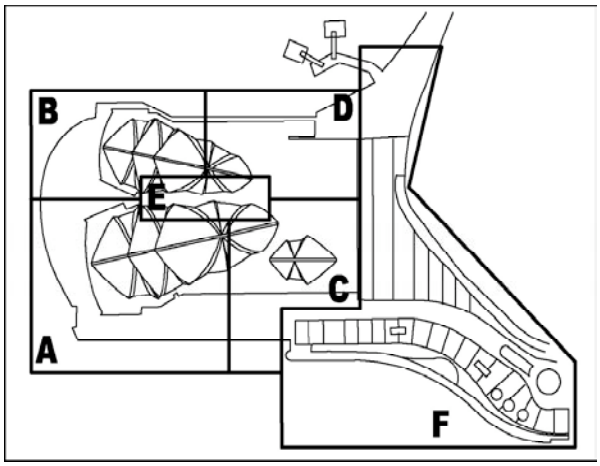
Rooms

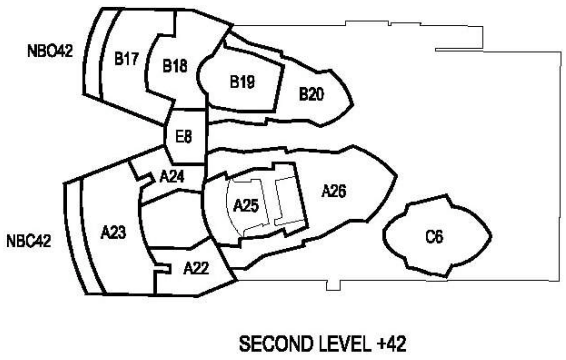
Places

2.5.1 Location Zones (LZ)

The SOH site is divided into areas A to F with an attached numeric code for subdivisions of the complex.

Table A.2: Location Zones





Note: Location Zone definitions for remote facilities to be advised.
Location Zones shall be represented by *ifcZone*

ifcZone

IFC Attribute	Setting
Name	One of LZ codes from Table A.2 above
Description	Not applicable
Object type	"Location Zone"
Long name	Not applicable
Complex type	Not applicable

Property Set usage is project and task dependent and shall be determined by SOH.

2.5.2 Functional Spaces (FS)

Organisational units within the Bennelong Point complex are termed Functional Spaces. Table A.3 below sets out the current scope.

Table A.3: Functional Space Codes

FS Code	FS Name	FS Definition
AE	Arts Exchange	Arts Exchange
BG	Building (general)	Works (including overheads & operations) not to a specific functional space, all plant rooms, general arrangements, total site plans/layouts
BX	Box Office	Box office, Call centre, Tours Office, Box office foyer including cloakrooms, toilets, stairs from forecourt
CH	Concert Hall	Auditorium including walls & ceilings, platform, backstage, control rooms, roof space (not shells), foyers, rehearsal & dressing rooms
CP	Central Passage	Stage door, central passage and bronze vehicle doors
DT	Drama Theatre	Auditorium, stage, backstage, control rooms, rehearsal & dressing rooms

FB	Food & Beverage	Facilities provided specifically for food and beverage services (Bennelong Rest, Cafe Mozart, Sidewalk Cafe, Opera Bar, 180 Degree, Dolce vita and any food/beverage contract space)
FC	Forecourt	Forecourt, upper podium, lower forecourt, broadwalks (eastern, northern, western), toilets
OT	Opera Theatre	Auditorium including walls & ceilings, backstage & dock, control rooms, roof space (not shells), foyers, rehearsal & dressing rooms
PH	Playhouse	Auditorium, stage, backstage, control rooms, rehearsal & dressing rooms
UR	Utzon Room	Hall and side rooms, access to Hall
RS	Recording Studio	Recording Studio and Edit Suite
SF	Staff	Facilities Staff and contractor areas, including corridors and common areas, not covered elsewhere including Green Room
SH	Shops	Facilities provided specifically for retail
ST	Studio	Auditorium, stage, backstage, control rooms, rehearsal & dressing rooms
WF	Western Foyer	Foyer and toilets, Exhibition Hall

Note: Functional Space definitions for remote facilities to be advised.
Functional Spaces shall be represented by the entity *ifcZone* linking *all* rooms contained in the Functional Zone

ifcZone

IFC Attribute	Setting
Name	One of FS codes from Table A.3 above (excluding BG Building (general)
Description	One of FS names from Table A.3 above (complementing the matching FS code)
Object type	"Functional Space"
Long name	Not applicable
Complex type	Not applicable

Property Set usage is project and task dependent and shall be determined by SOH.

2.5.3 Rooms (RM)

Rooms are an area that is defined by the building's major wall elements etc, (potentially not able to be removed).

Rooms in the Bennelong Point complex are numbered according to the following convention: <Storey code><sequential number>. The *Storey cod*e is either a character code eg SB or a number eg 1. Room names are documented on existing GA plans. See Base Building Architectural drawings.

Eg **GM574A Upper Plantroom #14** or **1527C Green Room Dining**

Note: Room name definitions for remote facilities to be advised.

SOH Room Types

ID	Type	ID	Type	ID	Type
1	Circles & Boxes	17	Lounge	33	Plantroom
2	Auditorium Stalls	18	Food Servery	34	Storage
3	Toilet and Airlock	19	Kitchen	35	Workshop
4	Public Foyer	20	Cool Room	36	Balcony
5	Box Office	21	Shop	37	Podium
6	Cloak room	22	Lift Well	38	Monumental Stairs
7	Rehearsal room	23	Lobby	39	External Stairs
8	Dressing Room	24	Stair	40	Lower Concourse
9	Wardrobe	25	Services Corridor	41	Forecourt
10	Control Rooms	26	Cleaners Room	42	Car Concourse
11	Stage Storage	27	Tea Room	43	Western Broadwalk
12	Stage/Backstage	28	Executive Office	44	Northern Broadwalk
13	Equipment Room	29	Manager's Office	45	Eastern Broadwalk
14	Locker Room	30	Meeting Room	46	Shells & Louvres
15	Bar Servery	31	General office		
16	Dining Area	32	Services Duct		

All *rooms* in the SOH shall be defined as an entity *ifcSpace*.

ifcSpace

IFC Attribute	Setting
Name	*Room number* as defined above
Description	Not applicable
Object type	*Room type* – the functional category of the room (according to SOH room type classification above)
Long name	*Room name* as defined above (complementing the matching Room number)
Complex type	Not applicable
Internal/External	As applicable; a room is external if it bounds an external face of the building.
Elevation wrt flooring	Height in mm from storey level on which it is located

Property Set usage is project and task dependent and shall be determined by SOH TIC.

2.5.4 Places (PL)

Places are sub-divisions of a room, ie the "child" of a Room (see above).

Note: The FAPI database records BPI against *Places,* however the main reporting mechanism presents the Place scores wrapped up to its parent room.

A *place,* within a room, is identified by adding a suffix to the room id (eg for room G539A, *G539A/1* is the first place within the room).

All Places in the SOH shall be defined as an entity *ifcSpace* and linked to their owning Room by an *ifcZone*.

IfcSpace - Place

IFC Attribute	**Setting**
Name	*Place number* as defined above
Description	Not applicable
Object type	"Place"
Long name	Not applicable
Complex type	Not applicable
Internal/External	As applicable; a place is external if it bounds an external face of the building.
Elevation wrt flooring	Height in mm from storey level on which it is located

IfcZone - Place

IFC Attribute	**Setting**
Name	*Room number* as defined above
Description	Not applicable
Object type	Not applicable
Long name	Not applicable
Complex type	Not applicable

Note: Each *Place* may have BCI data recorded in a custom PSET (see section **8.2 Building Condition Index**)

3. The Site Model & GIS

The SOH main complex is located on a site overlaid by a complex network of historical development, archeological artifacts, current and disused utilities, underwater and underground features. Information about this is sourced from many private and state utilities and government agencies, and in many different but principally GIS formats.
The objective of the SOH Master Model is to integrate this data in IFC format.

3.1 Cadastre

Cadastral data elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

3.2 Land Use

Land use data elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

3.3 Terrain

Terrain elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

3.4 Utilities

Utilities elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

4. Asset Register

Where model entities are part of the SOH Asset Register, data shall be attached to the entity in the form of a custom PSET, named "SOH Asset Register", and shall conform to the following:

IFC PSET "SOH Asset Register"

IFC Property	Setting
Reference	*Plant Reference* as defined by SOH eg "BG1147"
Description	*Plant Description* as defined above (complementing the matching asset item *Name)* eg "Lift No. 06")
Element	SOH Asset element classification Eg "Transportation"
ItemLocation	SOH *Room number* (see section above)*
Functional Space	See *FZ codes* above*
Parent	Owning *Plant reference* eg "BG1141 Lifts"
BarCode	The SOH bar code
InstallDate	Date of purchase (dd mmm yyyy format)
InstallCost	Cost in AUD of installing item
PurchaseCost	Cost in AUD of purchasing item

*** Note**: This data may be derived directly from the IFC model data

Property Set usage is project and task dependent and shall be determined by SOH.

5. The Architectural Model

5.1 Building Elements

Building elements (the term used in the IFC specification to describe the main building parts) are the most numerous in the model; where possible the following information shall be recorded:

Property	
Material (and layers) – in accordance with Australian Building Glossary or other definitive industry reference	*FireRating* – in accordance with BCA
AcousticRating - in accordance with BCA	*Combustible*
SurfaceSpreadOfFlame	*ThermalTransmittance*
LoadBearing	*Compartmentation*

This data shall be applied to the relevant property set eg for walls PSET_WallCommon, or if no such standard PSET exists then a custom PSET.

5.2 Slab, Beam, Column, Wall, Window, Door, Ramp, Stair and Railing Elements

Architectural elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

Note that all ifcEntities have a standard PSET which may be applicable according to the specific project and task.

5.3 Compartmentation & Fire Zones

Fire zones correspond to the Location Zones described earlier. Smoke Compartmentation shall be a subdivision of the LZ in accordance with the BCA and relevant authorities.

All smoke compartments shall be defined in accordance with *Location Zones* above.

6. Structural Engineering

Structural elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7. Building Services

Refer to the **Building Services Standard Specification** (BSSS and BSDM Building Services Designers Manual) for detailed design and performance criteria.

7.1 Mechanical Services

Mechanical Services elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.2 Electrical & Digital Communications

Electrical Services and Digital Communications elements are both designated disciplines and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.3 CAVS (Stage & Audio-visual Equipment)

CAVS elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.4 Security

Security elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.5 Hydraulic Services

Hydraulic elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.6 Transportation

Transportation elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

7.7 Equipment

Equipment elements are a designated discipline and shall conform to Section **1.5 SOH Sub-models** when exchanging data.

8. Asset Maintenance

The following information is vital for Asset maintenance and presentation.

Where model entities are part of SOH Asset maintenance or presentation, data shall be attached to the entity in the form of a custom PSET, named "SOH Asset Maintenance" and "SOH Building Condition Index" respectively and shall conform to the following:

8.1 Maintenance

IFC PSET "SOH Maintenance"

Property	Setting
Name	*Plant Reference* as defined by SOH eg "BG1147"
Description	*Plant Description* as defined above (complementing the matching asset item *Name* eg "Lift No. 06")
Element	SOH Asset element classification Eg "Transportation"
ItemLocation	SOH *Room number* (see section above)*
Functional Space	See *FZ codes* above*
Parent	Owning *Plant reference* eg "BG1141 Lifts"
Name	*Plant Reference* as defined by SOH eg "BG1147"
MaintenanceTaskSchedule	The SOH maintenance *Task Allocation* code

Note: refer to the *IFC PSET "SOH Asset Register"* in Section **4. Asset Register**

8.2 Building Condition Index

The *Building Condition Index*, a combination of a Building Fabric Index (BFI) and a Building Presentation Index (BPI), is a method the SOH has adopted to measure general appearance, tidiness and cleanliness of functional spaces of the building.

The BPI data shall be described in a custom PSET "SOH Building Condition Index"

IFC PSET "SOH Building Condition Index"

IFC Property	Setting
Name	*Asset Element* or *Place* as defined above
Description	*Asset name* as defined above (complementing the Asset name)
BFI Date	*dd/mm/yyyy* date the *Fabric Index* was measured
BFI Rating	*% rating* (see SOH BFI Scoring Structure)
BFI Target	% rating to be achieved
BFI Benchmark	Reference rating
BFI Note	Comments made at the measurement inspection
BFI Inspection Name	Reference for inspection
BPI Date	*dd/mm/yyyy* date the Presentation Index was measured
BPI Impression	*% rating* (see SOH BPI Scoring Structure)
BPI Cleanliness	*% rating* (see SOH BPI Scoring Structure)
BPI Tidiness	*% rating* (see SOH BPI Scoring Structure)
BPI Target	*% rating* to be achieved
BPI Benchmark	Reference rating
BPI Note	Comments made at the measurement inspection
BPI Inspection Name	Reference for inspection

9. Model Auditing

Model Data to be submitted for update of the SOH Master Model shall be audited[1] before submission. There are several levels of auditing:

- SOH BIMSS compliance
- IFC project data for controlled collaboration
- Model entity geometry & properties
- Model veracity

9.1 SOH BIMSS Compliance

The IFC file data must comply with all of this specification's requirements, such as setup of the model, the naming of stories, buildings, rooms etc.

9.2 IFC Project Data for Collaboration

Whenever an IFC model is created certain data is mandatory. The entities described in **Appendix B**, **Table 4: IFC Model – High level Entities** are termed the *IFC Project Data*.

An IFC Project may have multiple buildings and multiple sites, even if the receiver has only imported one of several buildings in an IFC source file. In the IFC model each story has a collection of building elements, described by geometry and property data.

Data for the high level entities is always exported, even if the export is filtered to a certain storey or excludes geometry data for example. For reliable collaboration, *the GUIDs for the high level entities **must** be identical with the SOH Master Model* to allow updating and merging. New entities (excluding the Project) may occur, but agreement from SOH must be given before creating these new entities.

9.3 Model Entity Geometry & Properties

The IFC specification supports many geometry representations. Consult with SOH to ensure that your application's IFC data meets these requirements.

All geometry shall be properly constructed so that abutting or related elements are represented faithfully.

Ensure that attribute data (mandatory properties required by the IFC specification) and Property set data (PSETs) meets SOH information, material etc standards.

9.4 Model Veracity

A model may meet the above criteria but still be unacceptable – for example a room might have no door. Ensure that model is consistent and logically correct.

[1] **Note**: Several commercial tools are available for this purpose, eg *Solibri Model Checker*, Finland, *NavisWorks Jetstream*, UK and *DesignCheck*, CRC-CI, Australia. IFC model servers such as *EDM Model Server*, EPM Norway and *Eurostep Model Server*, EuroSTEP also perform many customisable and sophisticated model auditing functions.

Appendix A: The IFC Integrated Object Model

A.1 What is an IFC?

IFC, in practice meaning "Information for Construction", is the set of internationally standardized object definitions for use in the Construction Industry developed by the International Alliance for Interoperability (IAI).

The business objective of the IAI, through its chapters established in some 11 countries around the world (refer http://www.iai-international.org) is:

> To integrate the AEC/FM industry by specifying Industry Foundation Classes (IFC) as a universal language to improve the communication, productivity, delivery time, cost, and quality throughout the design, construction, operation and maintenance life cycle

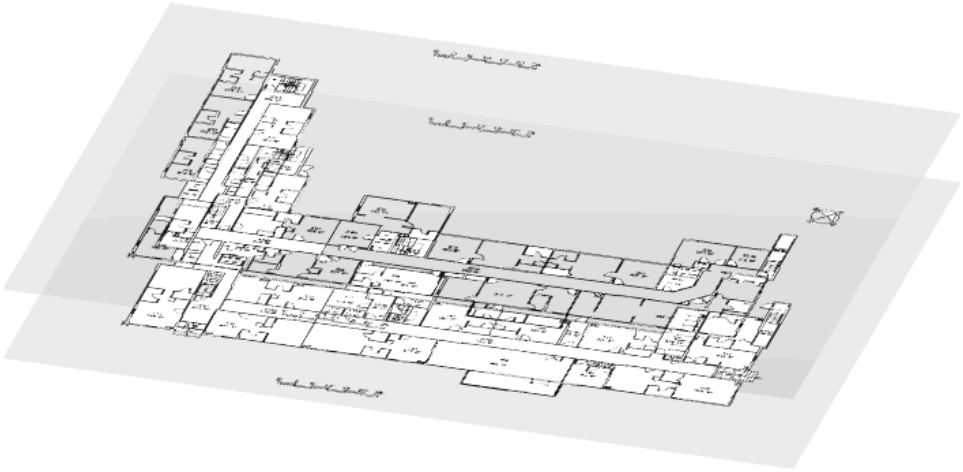


Figure 1: Traditional 2D CAD
2D CAD Information about a building is disconnected, is essentially "dumb"data and uses drawing views to document a building.

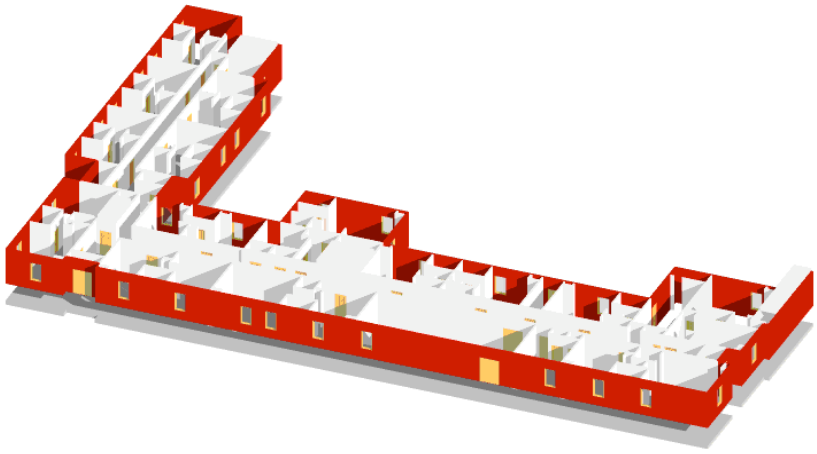


Figure 2: IFC based Building Information Models (BIM).
3D intelligent objects are the key advantage of the integrated model, which not only ensures consistency of data but supports performance simulation, visualisation and automation of production.

IFC is to "Project Model" exchange (wall, door, window) what DXF is to graphic entity exchange (line, arc, circle). IFC is available to all participants in the Construction Industry, for use globally, including use by all construction industry software vendors. IFC offers a higher-level "common language" for the sharing of intelligent objects between

disciplines across the building lifecycle

A.2 Inter-operability Definition

The IFC concept is based on the idea of objects brought together in an integrated model. These objects are defined to support the whole lifecycle of facility development from inception through design documentation and construction, then facility management and finally demolition and or disposal.

A.3 IFC Model Versions

The IFC protocol has developed over several releases and offers the following functionality:

IFC Version	Scope
1.51	The first release of the IFC model. This version supported the concept of building carcass.
2.0	Substantial extension of functionality over 1.5.1. Increased scope for cost estimating, thermal load calculations and HVAC design, client briefing and space layout for architectural design. Additional concepts are provided for special transfers
2x	The IFC2x2 platform release is stable until at least 2005/2006 to allow the industry to deliver mature interface support. Additional capabilities extending the IFC2x2 platform are planned to be introduced, but the solutions remain downward compatible, so that previous IFC2x2 files can be still read by the enhanced IFC2x2 interfaces.
2x2	The 2x2 Platform was extended by new functionality for building structures (steel, concrete including pre-cast, and timber, building services – HVAC, electrical, hydraulic and sanitary, extension of FM and some 2D entities.
2x3	Improvements to 2x2 – extensions of structural systems, building services and enhancements to the model
2x4	New functionality for Geographic Information System (GIS) and extensions for Bridges data. **Note**: This version will be released late 2006

Table 2: IFC Model Versions

A.4 Views

IFC cover a diverse range of information within building construction but the model does not distinguish who should be exchanging that information or at what point in a project the information is being exchanged.

Software applications are more usually concerned with specific requirements and should not have to implement or use every class that is contained within the IFC model. Therefore, subsets of the model are defined that, when isolated from the complete IFC model, still act as a coherent model. These subsets are called *views*.

Views are used to support the many different data needs of say asset manager, structural engineer, HVAC engineer or cost estimator for example.

IFC Version	View	Functionality
1.5.1	CAD view	The following entities are supported: Beam, Building, Building Storey, Column, Door, Floor, Opening Element, Project, Proxy, Roof Slab, Site, Space, Space Boundary, Wall, Window. This entity set is comprehensive enough to underpin a wide range of data sharing needs, based on the carcass of a building.
2.0	BLIS[1]	Four focused processes are supported:

	view set	• Architectural design >> Quantities take off / cost estimating • HVAC system design >> Quantities take off / cost estimating • Architectural design >> Thermal load calculations / HVAC system design • Client brief / space layout >> Architectural design See the BLIS reference below for detailed description of the view definitions and objects included.
2x2 and 2x2 Edition 2		Coordination View Code Checking – Singapore Building Plans.

[1] BLIS is a worldwide consortium of AEC application developers dedicated to developing IFC compliant products. See the website http://www.blis-project.org/ for more information.

Table 3: IFC Model Views

A.5 Useful links for Using the IFC Exchange Protocol

To understand more about the **International Alliance for Interoperability** (IAI), the worldwide chapters and the IFC development process see http://www.iai-international.org

To understand more about the **BLIS project** and definition of IFC 2.0 BLIS views see http://www.blis-project.org/

To find out the current availability of **IFC compliant applications,** IFC development tools and forthcoming products see http://www.bauwesen.fh-muenchen.de/iai/ImplementationOverview.htm

To get information about IFC software development and the IAI's **Implementation Support Group** (ISG) see http://www.bauwesen.fh-muenchen.de/iai/iai_isg/

Appendix B: Understanding IFC Model Data

B.1 The IFC Model

The structure follows the rules of the IFC model (**ISO/PAS 16739 – IFC 2x Platform**).

The key concepts are:

Entity	Description[2]	Restrictions (Yes, No)
Project	The undertaking of some design, engineering, construction, or maintenance activities leading towards a product. The project (*ifcProject*) establishes the context for information to be exchanged or shared, and it may represent a construction project but does not have to.	Yes. A Project must contain at least a Site or a Building. A Project may have many Sites, and many Buildings
Site	A defined area of land, possibly covered with water, on which the project construction is to be completed. A site (*ifcSite*) may be used to erect building(s) or other AEC products.	No. A Project does not necessarily contain any Sites.
Building	A building (*IfcBuilding*) represents a structure that provides shelter for its occupants or contents and stands in one place. The building is also used to provide a basic element within the spatial structure hierarchy for the components of a building project (together with site, storey, and space).	No. A Project may consist of just a single Site.
Storey	The storey (*IfcBuildingStorey*) has an elevation and typically represents a (nearly) horizontal aggregation of spaces that are vertically bound.	Yes. A Building must have at least one Storey.

Table 4: IFC Model - High Level Entities

In addition to the key entities described above there are many other entities which represent the parts of the building carcass (such as *walls* , *beams* and *columns)*, or *equipment* and *furniture*, or service systems (such as a fan or ductwork).

B.2 IFC Data

Whenever an IFC model is created certain data is mandatory. The entities described in **Table 4: IFC Model – High Level Entities** are termed the *IFC Project Data*. Data for these entities is always exported, even if you decide to filter the export to a certain storey or exclude geometry data for example.

As an IFC Project may have multiple buildings and multiple sites, the project data always includes the complete structure, even if you have only imported one of several buildings in an IFC source file.

In the IFC model each story has a collection of building elements, described by geometry and property data.

In summary there are three types of data in the IFC model, *geometry*, *property* and *relationship*:

B.2.1 Geometry Data

This data describes the shape of the physical parts of the building and site. It provides the three dimensional (3D) representation of the model. Many ways of representing the geometry are provided.

B.2.2 Property Data

Every entity in the model has two types of property data:

Attributes – formal definitions of an entity in the model, considered to be widely applicable (some of which are mandatory such as the GUID globally unique identifier), and

[2] See the **IFC 2x Edition 2, Amendment 1 Model** at http://www.iai-interoperability.org

Properties – additional descriptions of an entity, which are grouped in structures called property sets - PSET.

IFC based collaboration places more emphasis on Property Data than is normal with a 2D project; this is because each participant in an exchange – say the HVAC Engineer, wants not only the geometry, but also the nature and performance of objects (eg for a wall – its type, thermal transmission coefficient, orientation, etc – so that a thermal load can be calculated).

Property sets

The IFC Model defines standard PSETS for most elements; many elements may share values from a single PSET. Custom or user-defined PSETS may also be created.

B.2.3 Relationship Data

The relationships between parts of a building (or entities of the model more generally) is a distinguishing feature of the IFC model. Relationships allow users (and applications) to discover additional meaning from the data (which is why the IFC model is also called a *semantic* model – ie it has meaning). For example an application can check whether a room is connected to an external exit through the IFC model *spatial* relationships.

Two relationships are directly used:

Containment structure

This spatial structure describes the hierarchy of elements in the model, and is where most data is found and edited. See **Table 4: IFC Model - High Level Entities** for the key IFC entities.

Grouping information

Provides for collections of entities allowed by the model.

Appendix C: IFC Specification

For technical documentation about the IFC model refer to the following location:
http://www.iai-international.org/Model/IFC(ifcXML)Specs.html

Appendix D: Referenced Standards

Refer to http://www.tc184-sc4.org/SC4_Open/ for more details of the ISO/PAS standard 16739.