PROPERTIES FOR FIRE ENGINEERING DESIGN IN NEW ZEALAND AND THE IFC BUILDING PRODUCT MODEL

Michael Spearpoint,
Department of Civil Engineering, University of Canterbury
michael.spearpoint@canterbury.ac.nz

SUMMARY

This paper examines the information needs of Fire Engineers and relates those needs to the IFC Building Product Model. It identifies what is already provided in the IFC 2x Model and how in particular it corresponds with the New Zealand Approved Document Acceptable Solution C/AS1. The paper then demonstrates how Property Set Definitions can be used to extend the scope of the IFC Model for use by Fire Engineers.

FIRE ENGINEERING DESIGN

Fire engineering is only one of the domains in the AEC/FM industry that can benefit from electronic descriptions of buildings. It is a specialised discipline that requires its own domain specific elements as well as elements common to many of the other construction related domains.

Fire Engineers are involved in many aspects of a building's construction, fit-out and potential renovation. The New Zealand Building Code is a performance-based code that includes fire safety requirements with the objectives of providing means of escape to occupants, preventing the spread of fire to neighbouring property, providing protection to fire service personnel during fire-fighting and limiting the effects of fire on the environment. These objectives are met through the consideration of issues such as exit route design, fire and smoke spread mechanisms and structural stability and can be achieved by following published acceptable design methods or by considering alternative solutions using fire-specific design.

In order to carry out alternative designs, Fire Engineers are likely to conduct computer simulations particularly where the building is complex and there may be several fire scenarios that need to be considered. Much of the initial simulation effort is spent simply obtaining and transferring the basic building description into the specific fire/evacuation application. Very few of the currently available applications can import building information in an electronic form and even those that do are limited by the information available such as provided in a DXF file.

COMMON ELEMENTS

There are many aspects of a building that are common to the fire engineering domain and other domains such as architecture, structural engineering and building services. Fire Engineers need to have the basic geometry and topology of a building. This includes information such the size and shape of rooms, openings and hidden voids that could be a means of fire or smoke spread, the exits from a space and where those exits lead.

Fire Engineers are involved in the specification and design of specific fire safety systems such as alarm, suppression and smoke management systems. These will require details of system components (such as smoke detectors, sprinklers, fans) plus electrical wiring layouts, plumbing and pipe work, ducting networks etc.

Fire Engineers need to determine the fires that could likely occur through an assessment of the fuels in the building. This requires the Fire Engineers to determine the fire properties of lining materials, the contents of the spaces in terms of total fuel load, the arrangement of fuel packages and the relative flammability of those packages. Fuel packages might include furniture and fittings, stored items plus wall, floor and ceiling coverings.

Information regarding the site of the building may also be necessary. For example weather may be a factor and temperatures, wind velocities, humidity may all be required in order to specify the performance of the fire safety systems.

Finally Fire Engineers need to obtain details of the occupancy characteristics of the building. This may include information such as the primary use of the spaces, numbers of people, times when the building will be occupied and by whom, the physical and mental state of the occupants.

PROPERTY CATEGORIES

Within the context of fire safety, the properties of building elements can be thought of as belonging to three general categories.

- Category 1: the fundamental thermo-physical properties of a building element. These properties might include the thermal conductivity, specific heat capacity and so on.
- Category 2: fire specific properties that may have been obtained by measurement or some other means. Here we might include such things as the heat release rate (i.e. the energy release over time) and the properties of the smoke generated by a burning item.
- Category 3: properties that have been obtained for regulatory or standardisation purposes. These properties are generally obtained from some form of standard test method and are derived properties that have a specific regulatory meaning.

IFC BUILDING PRODUCT MODEL

The IFC Building Product Model is a general product model that provides an object-oriented description of many aspects of a building and related services enabling interoperability between different vendors of AEC/FM software. It aims to support the exchange of information throughout the design, construction and operation stages of a project. Development of the IFC Model began around 1996 and has continued through several versions up to the present IFC 2x release as specified by Liebich *et al.* (2000).

The IFC Model has the potential to allow Fire Engineers to automate compliance checking with published acceptable methods by the use of appropriately designed software applications. The IFC Model also can be used to allow Fire Engineers to extract relevant building-related information in order to conduct alternative designs using fire modelling applications. In each case, the form and level of detail available in the IFC Model will dictate the scope of either method. Mapping a general product model, such as the IFC Model, to a highly domain specific application can present limitations as demonstrated by Karola *et al.* (2002).

Many of the Category 1 fundamental properties that are useful for Fire Engineers are already available in IFC 2x. These include IfcEnergyMeasure, IfcHeatFluxDensityMeasure, IfcSpecificHeatCapacity-Measure, IfcThermalConductivityMeasure etc. There is scope to extend these fundamental properties so as to include additional ones that would be useful for Fire Engineers. This might include properties such as heat of combustion, apparent ignition temperature or the ability to have properties that are a function of some other parameter, for example, the thermal conductivity as a function of temperature. However many of these might be better seen as Category 2 properties as they might not be considered fundamental properties.

IFC 2x already recognises the fact that buildings contain elements with properties specifically related to fire engineering and these are shown in Table 1. Examining these properties closely we find that the majority of them are essentially Category 3 regulatory properties.

Property Set Definitions

As a general product model, it is not the intention of the IFC Model to provide a class for every type of object that could be encountered. Instead, object types are generalised at a relatively high level and these object types terminate at “IFC Leaf Nodes” (Figure 1).

Property set definition and associated IFC class	Fire specific property name	Data type	Definition
Pset_DoorCommon (IfcDoor)	FireRating	IfcString	Fire rating of complete door assembly. Given according to the national fire safety classification.
Pset_Insulation (IfcDiscreteElement)	FlamabilityRating	IfcString	Insulation flammability rating.
Pset_CoveringCommon (IfcCovering)	FireRating	IfcString	Rating indicating the time duration before fire would penetrate this ceiling
Pset_RoofCommon (IfcRoof)	FireRating	IfcString	Time duration for fire resistance the roof assembly is rated.
Pset_SlabCommon (IfcSlab)	FireRating	IfcString	Fire rating of slab.
Pset_SpaceCommon (IfcSpace)	MainFireUse	IfcString	Main fire use for the space which is assigned from the Fire Use Classification.
	AncillaryFireUse	IfcString	Ancillary fire use for the space which is assigned from the Fire Use Classification.
	FireRiskFactor	IfcInteger	Fire Risk factor assigned to the space
	SprinklerProtection	IfcBoolean	Indication whether the space is sprinkler protected (true) or not (false).
Pset_StairCommon (IfcStair)	FireRating	IfcString	Fire survival rating = length of time the stair enclosure/ assembly will survive in case of fire
	ExitStair	IfcBoolean	Is this stair counted as an exit stair in case of fire?
Pset_WallCommon (IfcWall)	FireRating	IfcString	Fire rating of wall assembly.
Pset_WindowCommon (IfcWindow)	FireRating	IfcString	Fire rating of complete window assembly. Given according to the national fire safety classification.
Pset_FireDamper, Pset_FireSmokeDamper (IfcDamper)	FireResistance-Rating	IfcReal	Measure of the fire resistance rating in hours (e.g., 1.5 hours, 2 hours, etc.).
	FusibleLink-Temperature	IfcThermo-dynamic-Temperature-Measure	The temperature that the fusible link melts.
	ControlType	IfcString	The type of control used to operate the damper (e.g., Open/Closed Indicator, Resetable Temperature Sensor, Temperature Override, etc.)
	Plus other associated properties…		
Pset_SmokeDamper (IfcDamper)	ControlType	IfcString	The type of control used to operate the damper.
	Plus other associated properties…		

Table 1. IFC 2x fire-related properties (not all damper properties shown).

In order to provide detailed properties for individual disciplines, domain specific models could be developed to supplement the general product model. The use of general product models or domain specific models have certain advantages and disadvantages as pointed out by Ito (1995).

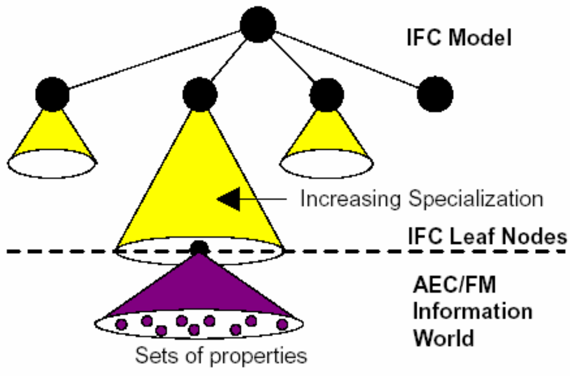


Figure 1. Limits of the IFC Model from Liebich & Wix (2000).

The IFC Model allows additional property sets to be attached to leaf nodes so that more detailed sets of properties can be accommodated in the model. These property sets must conform to the Property Set Definition (PSD) sub-schema of the IFC Model. Specialists within segments of the construction industry can carry out the task of defining property sets for IFC Model objects since such specialists will know what properties are relevant to a specific object.

NEW ZEALAND APPROVED DOCUMENTS

The Approved Document Acceptable Solution C/AS1 published by the BIA (2001) is one method in which a Fire Engineer can demonstrate that a building complies with the performance criteria of the New Zealand Building Code. C/AS1 is a set of design methods that address the fire safety requirements of buildings and includes a number of defined terms that have a specific regulatory meaning (shown in italics here and in C/AS1). C/AS1 is used by Fire Engineers for many simple, low-rise buildings in New Zealand.

We have already noted from Table 1 that the majority of fire specific properties in IFC 2x belong to our Category 3 regulatory properties. In the case of providing an automated compliance checking software tool, we investigate here how closely the fire-related properties in the IFC Model integrate with the regulatory requirements of C/AS1. In particular we are interested in finding where the IFC Model and C/AS1 have common components or where they differ and if so by how much. If there are differences we may still be able to match the IFC Model with C/AS1 if those differences are not significant. However if there are major differences, we may have to consider extensions to the core IFC Model by using the Property Set Definition mechanism.

Fire resistance

In most buildings certain elements are provided with a fire resistance in order to prevent the spread of fire and smoke or avoid structural collapse during a significant fire. In many cases this fire resistance is obtained from a standard furnace test such as ISO-834 (1999) and is specified as a failure time in minutes. C/AS1 specifies fire resistance ratings (*FRR*) using three numbers indicating values for *stability*, *integrity* and *insulation*. In some cases all three numbers will be the same, in others the numbers will differ and some may have a value of zero.

The FireRating property in IFC 2x allows the specification of the FRR to be provided for certain building elements. The FireRating property is used by the IfcWall, IfcDoor, IfcRoof, IfcStair, IfcWindow, IfcSlab and IfcCovering classes through several property set definitions as shown in Table 1. The use of the IfcString type for this property means that the *FRR* designation in the form of "*x*/*x*/*x*", where *x* are times in minutes for *stability*, *integrity* and *insulation*, can be accommodated.

Space utilisation

In order to assess the number and mobility of occupants, the activities undertaken and the nature of building materials and contents, C/AS1 categorises building spaces into *purpose groups* and *fire hazard categories* (*FHC*). C/AS1 contains around 16 specific *purpose groups* subdivided into four major activity sets that identify the broad use of the space. The four major activity sets are crowd, sleeping, working business or storage and intermittent. Examples of *purpose groups* for each activity set are Crowd Large (CL) for a cinema, Sleeping Accommodation (SA) for a hotel, Working Low (WL) for a factory containing materials that burn slowly and Intermittent Activity (IA) for a car park. Each *purpose group* also has an associated *FHC* designation that identifies the fuel characteristics in the space.

IFC 2x does not specifically contain properties for *purpose groups* and *fire hazard categories*. However the Pset_SpaceProgramOccupied property set, used by the IfcSpaceProgram class, contains a BldgCodeOccupancyType as an IfcString that essentially fulfils the role of identifying the purpose group. For *FHC*, the Pset_SpaceCommon property set associated with the IfcSpace class has two properties named MainFireUse and AncillaryFireUse, both of type IfcString type, in which either could be used to hold the *fire hazard category*. Alternatively a new property set specifically for C/AS1 could be created outside the core IFC 2x Model in which *purpose groups* and *fire hazard category* are explicitly defined.

Exit routes

For the design of escape routes C/AS1 has a number of specific definitions. These include *escape route*, *dead end*, *open path*, *protected path*, *safe path*, *exitway* and *final exit*. IFC 2x only has one property relevant to escape route design and this is the ExitStair property in Pset_StairCommon used by the IfcStair class. Although this property name is similar to the C/AS1 *exitway*, the specific regulatory definition in C/AS1 is "all parts of an *escape route* protected by *fire* or *smoke separations*, or by distance when exposed to open air, and terminating at a *final exit*". This means that there could be ambiguity where a stair forms part of the *escape route* but is not the whole *exitway*. It is clear that significant additions would need to be made to the IFC Model in order to incorporate the C/AS1 definitions for exit routes and this could only be achieved by the introduction of new property sets for spaces and stairs.

Material flammability

In addition to providing physical separations and the installation of fire safety systems, the control of internal fire and smoke spread can include an assessment of the burning characteristics of materials within a space. Such materials include surface finishes to walls, floor coverings, suspended fabrics and acoustic or thermal insulation materials.

C/AS1 provides a number of requirements for the burning characteristics of nearly all such materials through its spread of flame index (SFI), smoke developed index (SDI) and flammability index (FI). These indices are obtained from tests to AS/NZS 1530 (1999) parts 1-3 where the results are expressed as an integer value. Materials do not necessarily need to have all three indices specified depending on the requirements given by C/AS1. Floor coverings and membrane structures require separate tests in order to assess their burning characteristics and the outcomes of these tests are reportedly differently to the AS/NZS 1530 indices.

IFC 2x only has one instance where material flammability is explicitly referenced and this is in the Pset_Insulation property set in which the FlamabilityRating property is provided as an IfcString. The Pset_Insulation property set is used by the IfcDiscreteElement class which defines elements in a building services system such as insulation or attaching elements

C/AS1 requires that pipe insulation and acoustic treatments only be assessed in terms of their SDI and SFI and so the FlamabilityRating property has little use in conjunction with C/AS1. It is clear that all relevant elements in the IFC Model need to have new property sets in order to include the flammability requirements of C/AS1.

Dampers

Dampers are used to automatically close off an airway between fire-separated parts of a building. C/AS1 defines a *fire damper* and requires it has a specified *FRR*. IFC 2x includes properties for three types of fire-related damper all used by the IfcDamper class. The Pset_FireDamper, Pset_FireSmokeDamper both contain a property called FireResistanceRating however, unlike the FireRating property for walls etc., this property is of type IfcReal which means it is not able to hold the "*x*/*x*/*x*" *FRR* classification required in C/AS1.

HEAT RELEASE PROPERTY SET DEFINITION

Where a Fire Engineer chooses to provide an alternative solution to the published Acceptable Solutions they will often need to examine the fire and smoke conditions in a building. They will frequently have to devise one or more credible worst-case scenarios that will include a 'design fire curve'. Specifying a design fire curve requires certain properties of materials and items that may burn. Babrauskas and Peacock (1992) suggest that the most important of those material properties is the Heat Release Rate (HRR). The HRR can be obtained from basic material properties for simple fuels such as hydrocarbon liquids but more typically from experiments for fuels found in buildings such as furniture and linings.

Databases of experimental HRR are available and in particular the XML-based database called FireBaseXML developed by Spearpoint (2001) is relevant here. The database is already being used from within the BRANZFIRE fire modelling software developed by Wade (1999) but is also accessible through web-browser tools or alternative software.

IFC *R3.0* Property Set Definition Reference

PropertySet Definition:

PropertySet Name	Pset_FurnitureHeatRelease
Typed	False
TypedClass	
TypeName	
Definition	Definition from MJS, University of Canterbury

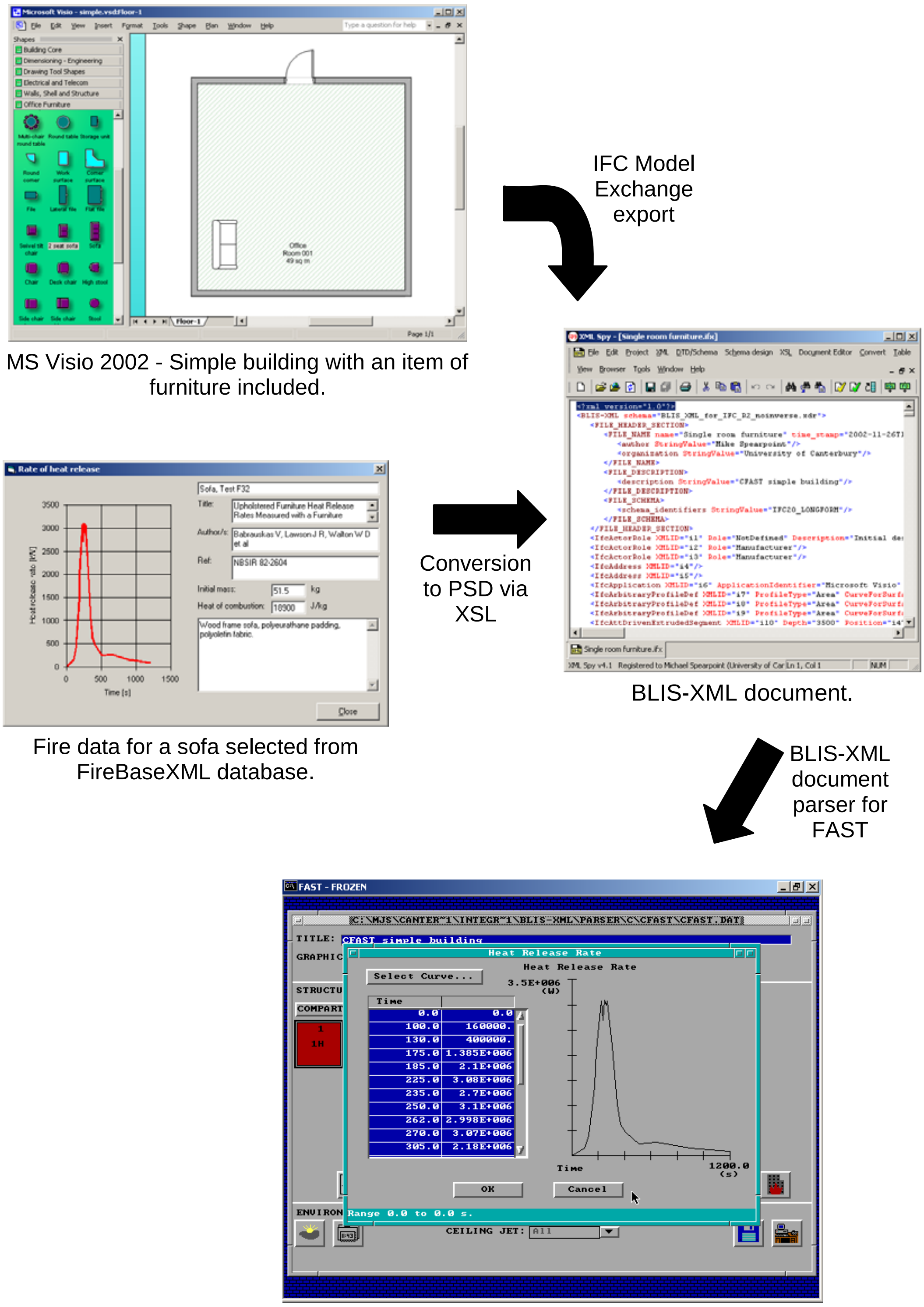
Property Definitions:

Name	Property Type	Data Type	Definition
HeatOfCombustion	IfcPropertySingleValue	IfcReal / UserDefined	The average heat of combustion
RateOfHeatRelease	IfcPropertyTableValue	**Defining Value:** IfcTimeMeasure / TIMEUNIT **Defined Value:** IfcEnergyMeasure / ENERGYUNIT	Time series rate of heat release
OriginalTestID	IfcPropertySingleValue	IfcText	The original ID of the test taken from the FireBaseXML database

Figure 2. A Pset_FurnitureHeatRelease Property Set Definition (Defining and Defined Values not shown).

Data from a FireBaseXML database can be transformed to an appropriate IFC PSD through a specific XSL transformation and Figure 2 shows the content of a Pset_FurnitureHeatRelease PSD formatted using the XSL transformation developed by Adachi (2002). The PSD contains the necessary heat release rate data as an IfcPropertyTableValue, the average heat of combustion as an IfcProperty-SingleValue (the units are J/kg and so are specified as UserDefined since these units do not currently exist in the IFC 2x Model) plus a reference to the original item ID in the FireBaseXML database.

The Pset_FurnitureHeatRelease PSD can be added to an IFC Model instance and assigned to one or more items of furniture. Once added to the IFC Model instance, the heat release rate for items can be used when transferring the building description into a fire modelling application.



MS Visio 2002 - Simple building with an item of furniture included.

BLIS-XML document.

Fire data for a sofa selected from FireBaseXML database.

FAST - Building description and fire properties transferred from BLIS-XML document.

Figure 3. The IFC Model exchange process into the FAST fire modelling application.

An example is shown here where a simple building has been created using the BLIS-XML specification developed by BLIS Project Companies (2002). Although the BLIS-XML specification uses IFC Release 2.0 and not IFC 2x the principles are the same. A simple square one-room building was created in Microsoft Visio 2002 in which a single item of furniture was included (Figure 3). This building was exported as a BLIS-XML document using the IFC Model Exchange functionality provided by Visio. An appropriate HRR curve was extracted from a FireBaseXML database, converted to a Pset_FurnitureHeatRelease PSD and added to the BLIS-XML document. This document is then translated into an input file for the FAST (Fire And Smoke Transport) fire modelling application developed by Bukowski *et al.* (1989) in which a furniture item and its associated heat release rate have been included. The dimensions of the room, the exit from the room and the wall material properties are also transferred from the BLIS-XML document to the FAST model. The fire modelling application is now ready for the Fire Engineer to continue with their fire modelling and design.

CONCLUSION

The current IFC 2x model provides much general information useful to the Fire Engineer. The fire specific properties that currently exist in the IFC Model have limited scope when compared to the needs of Fire Engineers and the ability of the properties to describe the New Zealand C/AS1 requirements. Property Set Definitions can be used to extend the IFC Model so as to include additional fire-related properties. We have shown how we are able to link a HRR database to an IFC Model document using a PSD and transfer the document to a fire modelling package. Significant further work is required to enhance the fire specific properties of the IFC Model either through additional PSDs or eventually by updating the core IFC Model.

REFERENCES

Adachi Y (2002), *PSD Worksheet reference*. International Alliance for Interoperability, MSG-01-2002, Draft 1.

AS/NZS 1530.3 (1999). *Simultaneous determination of ignitability, flame propagation, heat release and smoke release,* Standards New Zealand.

Babrauskas V, Peacock R (1992). *Heat release rate: The single most important variable in fire hazard.* Fire Safety Journal 18 (3) 255-272.

BLIS Project Companies (2002). *Building Lifecycle Interoperable Software - Project Brief*. http://www.blis-project.org (Accessed December 2002).

BIA (2001). *Approved Document for New Zealand Building Code, Fire Safety Clauses. Acceptable Solution C/AS1*. Building Industry Authority, Wellington, 2001.

Bukowski R, Peacock R, Jones W, Forney C (1989). *Technical Reference Guide for HAZARD I*. NIST Handbook 146, Volume II. Gaithersburg, National Institute of Standards and Technology.

Ito K. (1995) General product model and domain specific product model in the A/E/C industry. Proc. 2nd Congress on Computing in Civil Engineering, Atlanta, GA. vol 1 p 13-16

ISO 834-1 (1999). *Fire-resistance tests - Elements of building construction*. International Organization for Standardization.

Karola A, Lahtela H, Hänninen, Hitchcock R, Chen Q, Dajka S, Hagström (2002). BSPro COM-Server – interoperability between software tools using industrial foundation classes. Energy and Buildings 34 p 901-907

Liebich T, Wix J, ed. (2000). *IFC technical guide, Industry Foundation Classes – Release 2x*, International Alliance for Interoperability.

Spearpoint M (2001). *The development of a web-based database of rate of heat release measurements using a mark-up language*. Proc. 5th Asia-Oceania Symposium on Fire & Technology, Newcastle, Australia. 2001.

Wade C (1999). *BRANZFIRE: Engineering software for evaluating hazard of room lining materials.* Proc. 8th International Interflam Conference, Volume 2. Interscience Communications Ltd., London, England, pp.1147-1152.