FIRE ENGINEERING PROPERTIES IN THE IFC BUILDING PRODUCT MODEL AND MAPPING TO BRANZFIRE

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ABSTRACT

The Industry Foundation Class (or IFC) Model is a standardised, object-oriented "building product model" that provides an electronic description of buildings. Entities are defined in the model to represent building elements with their associated properties. This paper reviews the latest release of the IFC Model considering entities and properties related to fire engineering. The paper goes on to examine how these entities and properties can be mapped to the input requirements of the BRANZFIRE fire simulation software.

1. INTRODUCTION

Performance-based fire engineering design often involves the development and analysis of fire scenarios using fire simulation software (commonly referred to as 'fire models'). In order to carry out the design process, a considerable amount of time can be spent specifying the input to the simulation software prior to execution. Information such as the geometry and topology of a building, the location of items within the building and the properties of those items may be required. In addition the fire performance measures associated with the structure, the building contents and fire protection equipment are often desired as inputs to fire simulation software. All of this information can be quite voluminous and needs to be accurately transferred to the simulation software. Mistakes and missing information can lead to inappropriate output.

Traditionally, such information is entered manually even when the building plans may have been generated by Computer Aided Design (CAD) software. Yet where there is the ability to directly transfer CAD data into fire simulation software there can be significant limitations. These limitations stem from a variety of reasons including where the fire simulation software tool may be incapable of interpreting any kind of CAD file or where the CAD file does not adequately describe the building in a form from which the software can extract relevant details. Various solutions to the transfer of CAD data into fire simulation software and more general simulation software have been addressed elsewhere. Some researchers have investigated techniques to automate the recognition of paper-based drawings in a form that can be interpreted by CAD software [1]. Massa and Cappuccio [2] investigated the feasibility of adapting a proprietary topological analysis CAD system for modelling bomb blast effects as an interface to fire simulation software and concluded that implementation was readily achievable although it is unclear whether any further development was undertaken. Frost et al. [3] developed methods to transfer DXF files into the SMARTFIRE computational fluid dynamics fire simulation software. Similarly, the Simulex evacuation model [4] allows the direct import of CAD data through DXF files. Often these methods require that the original files be manually "cleaned" of data that would otherwise be incorrectly interpreted by the target software. The limitations of the DXF format also mean that only basic geometry primitives can be derived from the files because the format does not allow more detailed definition of objects [5].

Overcoming the current limitations of data exchange between CAD and fire simulation software requires a much richer description of buildings than typical formats such as DXF can provide. Mowrer and Williamson [6] identified the key features required by CAD systems to permit integration with fire simulation software. These characteristics included object-orientation, the association of attributes with objects and the ability to extract attributes from a CAD-developed drawing database. The IFC Model implements many of these features and thus is ideally suited to further investigation.

2. FIRE SIMULATION SOFTWARE

A recent survey [7] has shown that there are a wide range of fire simulation software tools available. The tools can be used for various fire engineering related tasks such as predicting fire and smoke spread, determining the performance of structural elements under fire conditions and the analysis of people movement in buildings or other premises. The software tools vary in the extent of the fire hazard scenario represented and subsequently the complexity of the input requirements and the sophistication of the output capabilities.

Zone models are a common category of fire simulation software available to the fire engineer. Quintiere [8] provides a description of the basic conservation equations and relationships that are used by most zone fire simulation software. The atmosphere within a compartment is normally split into two zones; the hot upper gas layer due to the fire and the cool layer below. The physical conditions within these layers are considered vertically and horizontally uniform. The fire plume transports combustion products from the lower layer to the upper layer and gases flow through vents in compartment boundaries. Although zone fire simulation tools all follow the same basic philosophy regarding the way in which the fire environment is represented, individual software tools may have facilities that are not present in others.

BRANZFIRE [9,10] is a widely available multi-compartment zone model. It can simulate the movement of smoke between up to 10 inter-connected spaces. Fires are specified by a rate of heat release curve or using a built-in fire spread model in the case of room linings. The model also has the ability to incorporate sprinkler and smoke detector activation, the breaking of window glass [11] and the effects of mechanical fans. Although the mapping of the IFC Model to the BRANZFIRE fire simulation software is specifically explored in this paper, the issues are representative of those faced integrating many of the available zone fire simulation software family.

3. PRODUCT MODELS

3.1 General Description

In general, any product can be considered to consist of a collection of *entities*. A *product model* expresses the type of entities that represent the product; the properties that are needed to describe those entities and the inter-relationship between entities. The description of a product model is commonly known as its *schema*. A *building product model* is a product model that specifically relates to buildings where entities may be physical objects such as doors, windows, walls etc. or more conceptual entities such as spaces or processes, contractual details etc.

Fire engineering is one of many domains including architecture, structural engineering, environmental engineering and building services which can benefit from using building product models [12]. Many parameters related to a building are common to a range of disciplines including fire engineering. These parameters may include the building geometry and topology, the materials and components used in the construction and the location of the structure within the broad environment. However, due to the specialised needs of fire engineering, there are also parameters that are unique to the domain.

3.2 Product Model Scope

Product models can be thought of being of two types; either they are general or they are domain specific [13]. A general product model supports the generation and sharing of project data through the complete building lifecycle amongst a diverse range of domains. A general product model does not attempt to include every aspect of a product as this would likely be too complex and take too long to develop. Instead a general product model describes entity types at relatively high level.

Conversely, domain specific models retain as much of the project data as required for use within a domain. For the fire engineering domain it is likely that a general product model will not provide all of the detail needed for fire simulation software tools or any other tasks related to fire engineering. A domain specific product model could be created which has all those entities relevant to the fire engineering domain but this can lead to problems when sharing that project data with participants in other domains. There would need to be a number of software tools available to interpret each domain specific model. Furthermore, domains outside fire engineering might find the domain specific model has essential information missing or not in a form that is useable by them.

Even where a product model completely describes a domain, it is possible that specific software tools may only implement a reduced proportion of the whole product model. This can mean that although the product model has an entity described within its schema, the software tool cannot be used to create a specific instance of that entity or completely populate the properties associated with the entity. In some cases it may be possible to manually add entities in lieu of having an appropriate software tool.

Finally the interpretation of the product model may lead to complications. The structure of entities may not be compatible with the specific requirements of the target software tool. This can happen where there is insufficient detail in the product model but also where the requirements of the software tool include simplifications and assumptions about a product that need to be accounted for during the data transfer process.

3.3 IFC Model

The IFC Model is a general building product model that began development around 1996 and has gone through several major releases to date. The latest version of the IFC Model is 2x Edition 2 [14] referred to as "IFC 2x2" in this paper, with corrections published in Addendum 1. Primarily IFC files are exchanged using STEP (Standard for the Exchange of Product model data) technology, ISO 10303 [15].

The IFC Model addresses the limited scope of a general product model using *property set definitions*. The high level entities terminate at *leaf nodes* which allow object types to be extended using the property set definition sub-schema. The specification of property set definitions can be made outside of the main IFC Model by specialists within their domain. Even with the use of property set definitions, there may still be specific object types missing or incomplete simply due to the fact that nobody has yet included the information in the product model. This has been the case with many of the entities that might be of use to fire engineers. A review of the properties in the earlier version 2x of the IFC Model with respect to fire engineering found that whilst there are a number of fundamental material properties and several regulatory-related properties in the IFC Model, there are also many areas in which the model can be extended [16]. Release IFC 2x2 has significantly greater support for fire engineering than the previous IFC 2x Model. In particular, IFC 2x2 has a specific domain referred to as the *IfcPlumbingFireProtectionDomain* which covers aspects of fire extinguishing systems. However, there are many other entities and properties that are relevant to fire engineering scattered throughout the IFC 2x2 Model and these are mentioned briefly in this paper. Fig. 1 shows the structure of the IFC Model and the underlined text indicates items that are applicable to this paper.

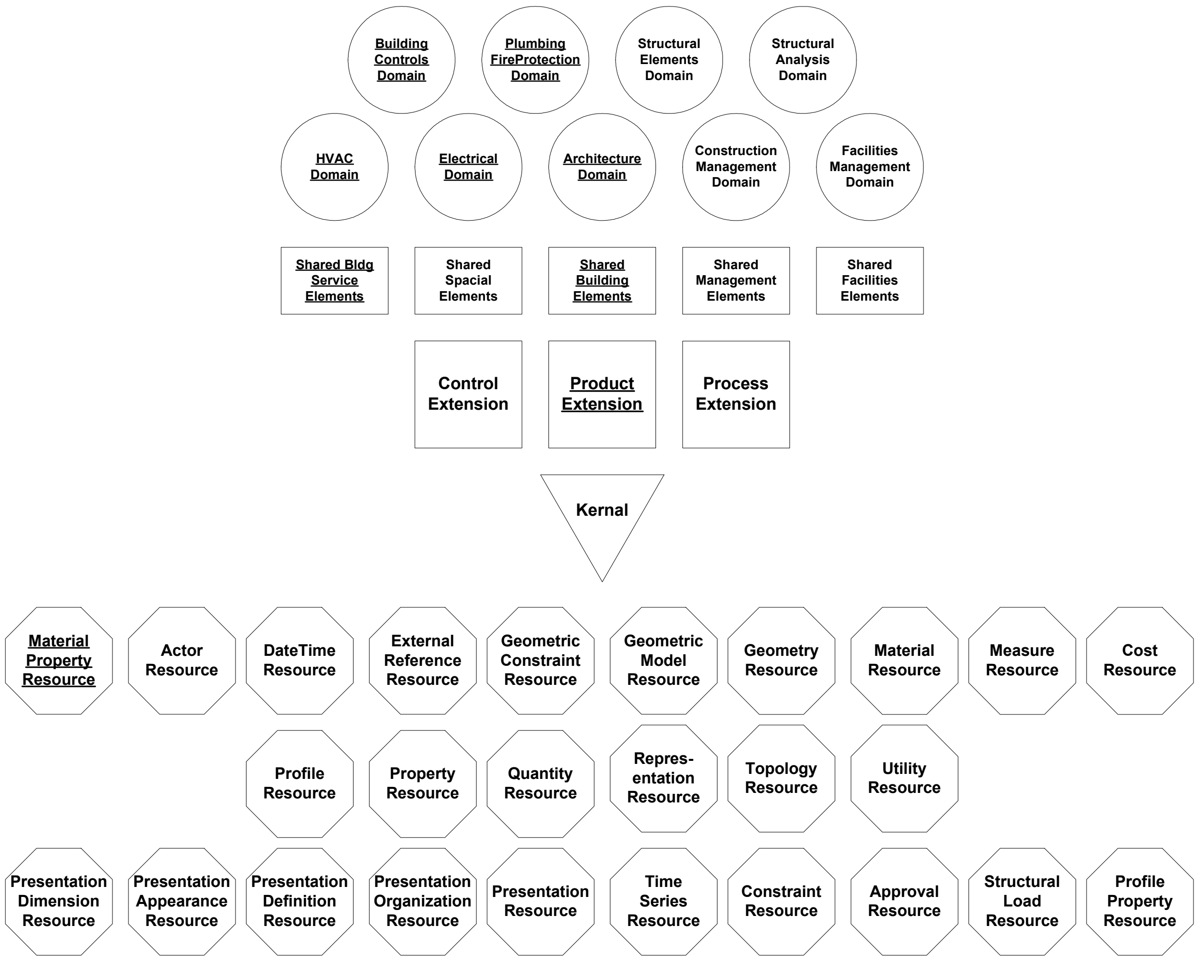

Fig. 1: IFC 2x2 schema overview (adapted from ref. [14])

The contents of the IFC Model are identified with a specific convention which is followed in this paper and is indicated hereafter in italicised text. Entities are prefixed with *Ifc*; property sets prefixed with *Pset* and enumerated lists of entities or properties with the addition of *Enum*.

4. PROPERTY SET MAPPINGS

4.1 Building Spaces

The IFC Model has entities that relate to buildings as a whole and the spaces that form those buildings. Several of these entities have properties that relate directly to fire engineering. Zones and spaces have specific fire engineering properties defined in the *Pset_SpaceFireSafetyRequirements* property set. The properties consider the use of the space through the *MainFireUse*, *AncillaryFireUse* and *FlammableStorage* properties; associated risks and hazards with the *FireRiskFactor* and *FireHazardFactor* properties; provisions for means of escape with the *FireExit* property and any active fire protection systems in the space by the use of the *SprinklerProtection*, *SprinklerProtection-Automatic* and *AirPressurization* Boolean properties. Similar properties are associated with the *IfcBuilding* and *IfcBuildingStorey* entities with a supplementary *ProtectedOpening* property associated with the *Pset_OpeningElement* property set.

In addition to the means of escape provisions specified in the property sets associated with buildings and spaces, IFC 2x2 also includes properties that provide the occupancy characteristics of spaces in the *IfcArchitectureDomain* layer. The *OccupancyType* is defined according to the presiding national building code and the *OccupancyNumber* specifies the maximum number of occupants for the designed usage of the space.

4.2 Structural Elements

Table 1 shows the fire engineering properties for structural elements defined in IFC 2x2. The properties identify fire and smoke containment with the *FireRating*, *SmokeStop*, *SelfClosing* and *Compartmentation* properties; the performance of materials with the *Combustible* and *SurfaceSpreadOfFlame* properties and means of escape provisions through the *FireExit* property (similar to the property associated with buildings and spaces).

IFC 2x2 also includes a general property set *Pset_FireRatingProperties* in the *IfcSharedBldgServiceElements* interoperability layer. This property set includes a *FireResistanceRating* property which appears to fulfil the same function as the *FireRating* property used for the fire resistance of structural elements. Similarly, an *IsCombustible* property in *Pset_FireRatingProperties* appears to fulfil the same function as the *Combustible* property for structural elements.

The fire engineering properties related to building spaces and structural elements have potential contribution to the regulatory environment and as input to other fire simulation software but in terms of mapping to BRANZFIRE, these properties have no directly equivalent parameters.

4.3 Fire Suppression Systems

The *IfcPlumbingFireProtectionDomain* contains several property sets related to fire extinguishing systems. The IFC 2x2 documentation [17] defines the *IfcFireSuppressionTerminalType* as a "particular type of *IfcFlowTerminal* that has the purpose of delivering a fluid (gas or liquid) that will suppress a fire" and includes all forms of sprinkler, spreader and other form of terminal that is connected to a pipe system. The specific types of *IfcFireSuppressionTerminalType* are defined in Table 2.

The four property sets associated with the *IfcFireSuppressionTerminalType* are *Pset_FireSuppressionTerminalTypeBreechingInlet*, *Pset_FireSuppressionTerminal-TypeFireHydrant*, *Pset_Fire-SuppressionTerminalTypeHoseReel and Pset_Fire-SuppressionTerminalTypeSprinkler.* The first three of these property sets are not applicable to BRANZFIRE because there are no directly equivalent parameters however the *Pset_FireSuppressionTerminalTypeSprinkler* is of particular relevance since BRANZFIRE can be used to predict sprinkler activation and sprinkler suppression of fires.

Fig. 2 shows the details regarding the *Pset_FireSuppressionTerminalTypeSprinkler* property set. BRANZFIRE requires the Response Time Index (RTI) and Conduction (C) factor, activation temperature, radial distance to fire and distance below ceiling. Of these, the last parameter can be obtained from the space geometry and the radial distance may be determined if the location of the fire can be identified but only the *ActivationTemperature* is explicitly supplied in the property set. BRANZFIRE has the option to specify the water spray density and this can be obtained from *Pset_Fire-SuppressionTerminal TypeSprinkler* through the *CoverageArea* and *DischargeFlowRate* properties.

Table 1: Fire engineering properties for structural elements defined in IFC 2x2

Property name and data type	Definition	Property set definition and associated IFC entity									
		Pset_BeamCommon (IfcBeam)	*Pset_ColumnCommon (IfcColumn)*	*Pset_CurtainWallCommon (IfcCurtainWall)*	*Pset_DoorCommon (IfcDoor)*	*Pset_RampCommon (IfcRamp)*	*Pset_RoofCommon (IfcRoof)*	*Pset_SlabCommon (IfcSlab)*	*Pset_StairCommon (IfcStair)*	*Pset_WallCommon (IfcWall, IfcWallStandardCase)*	*Pset_WindowCommon (IfcWindow)*
FireRating (*IfcLabel*)	Fire rating for object as defined by a national fire safety classification.	x	x	x	x	x	x	x	x	x	x
Combustible (*IfcBoolean*)	Indicates whether object is made from combustible material.		x					x		x	
SurfaceSpread OfFlame (*IfcLabel*)	Surface flame spread as defined by a national building code that governs fire behaviour of materials.		x					x		x	
FireExit (*IfcBoolean*)	Indicates whether object is designed to serve as an exit in the case of fire as defined by a national building code.				x	x			x		
SelfClosing (*IfcBoolean*)	Indicates whether object is designed to close automatically after use.				x						
SmokeStop (*IfcBoolean*)	Indicates whether object is designed to provide a smoke stop.				x						x
Compartmentation (*IfcBoolean*)	Indicates whether object is designed to serve as fire compartmentation.							x		x	

Table 2: IFC 2x2 values and definitions for the *IfcFireSuppressionTerminalTypeEnum* entity (adapted from ref. [17])

Value	**Definition**
BREECHINGINLET	Symmetrical pipe fitting that unites two or more inlets into a single pipe.
FIREHYDRANT	Device, fitted to a pipe, through which a temporary supply of water may be provided.
HOSEREEL	A supporting framework on which a hose may be wound.
SPRINKLER	Device for sprinkling water from a pipe under pressure over an area.
SPRINKLERDEFLECTOR	Device attached to a sprinkler to deflect the water flow into a spread pattern to cover the required area.

PropertySet Name	*Pset_FireSuppressionTerminalTypeSprinkler*
Applicability	*IfcFireSuppressionTerminalType* entity.
Applicable Type Value	*SPRINKLER*
Definition	Device for sprinkling water from a pipe under pressure over an area.

Property Definitions:

Name	Data Type	Definition
SprinklerType	*PEnum_SprinklerType*† • Ceiling • Concealed • Cut-off • Pendant • RecessedPendant • Sidewall • Upright	Identifies the predefined types of sprinkler from which the type required may be set.
Activation	*PEnum_Sprinkler Activation*† • Bulb • FusibleSolder	Identifies the predefined methods of sprinkler activation from which that required may be set.
Response	*PEnum_Sprinkler Response* • Quick • Standard	Identifies the predefined methods of sprinkler response from which that required may be set.
ActivationTemperature	*IfcThermodynamic TemperatureMeasure*	The temperature at which the object is designed to activate.
CoverageArea	*IfcAreaMeasure*	The area that the sprinkler is designed to protect.
HasDeflector	*IfcBoolean*	Indication of whether the sprinkler has a deflector (baffle) fitted to diffuse the discharge on activation.
BulbLiquidColor	*PEnum_SprinklerBulb LiquidColor*† • Orange • Red • Yellow • Green • Blue • Mauve	The colour of the liquid in the bulb for a bulb activated sprinkler. Note that the liquid colour varies according to the activation temperature requirement of the sprinkler head. Note also that this property does not need to be asserted for quick response activated sprinklers.
DischargeFlowRate	*IfcVolumetricFlowrate Measure*	The volumetric rate of fluid discharge.
ResidualFlowingPressure	*IfcPressureMeasure*	The residual flowing pressure in the pipeline at which the discharge flow rate is determined.
DischargeCoefficient	*IfcReal*	The coefficient of flow at the sprinkler
MaximumWorkingPressure	*IfcPressureMeasure*	Max. pressure object is manufactured to withstand.
ConnectionSize	*IfcPositiveLength Measure*	Size of the inlet connection to the sprinkler.
FrameMaterial	*IfcMaterial*	Material used to construct the frame of sprinkler.
DeflectorMaterial	*IfcMaterial*	The material used to construct the deflector plate.

† also includes Other, NotKnown and Unset values.

Fig. 2: The IFC 2x2 *Pset_FireSuppressionTerminalTypeSprinkler* property set (adapted from ref. [17])

The addition of properties for simulation purposes such as an RTI and C-factor and extending the range of characteristics available in the *SprinklerType, Activation* and *Response* properties would be beneficial as further enhancement to the *Pset_Fire-SuppressionTerminalTypeSprinkler* property set in future releases of the IFC Model.

4.4 Fire Detection and Alarm Systems

IFC 2x2 includes several entities in the *IfcBuildingControlsDomain* which are relevant to fire detection and alarm systems through the *IfcDistributionControlElementType* entity. The *IfcSensorType* entity contains several types of sensor either directly or indirectly applicable to fire detection. The *IfcAlarmType* entity contains several types of alarm activation and alarm indication devices. The *IfcAlarmType* defines "a device that signals the existence of a condition or situation that is outside the boundaries of normal expectation", and defines the range of different types of alarm that can be specified. However IFC 2x2 does not provide property sets for any of the *IfcAlarmType* entities. Since BRANZFIRE does not include any human behaviour modelling, these properties are not relevant to the current mapping exercise.

The IFC 2x2 documentation [17] defines the *IfcSensorType* as "a particular type of sensor which is used for detection in a control system". A list of the defined types of sensor is given in the *IfcSensorTypeEnum* enumeration type as shown in Table 3.

IFC 2x2 has several thermal sensor type property sets that are potentially applicable to fire detection systems and could be mapped to BRANZFIRE. IFC 2x2 differentiates between a temperature sensor and a heat sensor even though they are essentially the same device since they both use temperature as their method of detection. The properties used by these two entities differ slightly in that the *HEATSENSOR* includes a *CoverageArea* property which specifies the area covered by the sensor (Fig. 3) and the *TEMPERATURESENSOR* includes a *TemperatureSensorType* property which is used to specify the type of sensor. The existence and nature of the differences suggest that the *HEATSENSOR* is most applicable to fire protection.

IFC 2x2 also defines the a *Pset_SensorTypeFireSensor* property set (Fig. 4) which appears to be a surrogate for a heat detector since the property set includes the *FireSensorSetPoint* property which has a data type of *IfcThermodynamicTemperature-Measure*. However, this sensor appears to be surplus to requirements with the inclusion of the *Pset_SensorTypeHeatSensor* property set which essentially fulfils the same role.

For smoke detection, IFC 2x2 defines the *Pset_SensorTypeSmokeSensor* property set associated with SMOKESENSOR (Fig. 5). It is interesting to note that this property set includes the *HasBuiltInAlarm* property which would allow for a definition of a smoke alarm.

Table 3: IFC 2x2 values and definitions for the *IfcSensorTypeEnum* entity (adapted from ref. [17])

Value	Definition
CO2SENSOR	A device that senses or detects carbon dioxide.
FIRESENSOR	A device that senses or detects fire.
FLOWSENSOR	A device that senses or detects flow.
GASSENSOR	A device that senses or detects gas.
HEATSENSOR	A device that senses or detects heat.
HUMIDITYSENSOR	A device that senses or detects humidity.
MOVEMENTSENSOR	A device that senses or detects movement.
PRESSURESENSOR	A device that senses or detects pressure.
SMOKESENSOR	A device that senses or detects smoke.
TEMPERATURESENSOR	A device that senses or detects temperature.

PropertySet Name	*Pset_SensorTypeHeatSensor*
Applicability	*IfcSensorType* entity.
Applicable Type Value	*HEATSENSOR*
Definition	A device that senses or detects heat.

Property Definitions:

Name	Data Type	Definition
CoverageArea	*IfcAreaMeasure*	The area that is covered by the sensor (typically measured as a circle whose centre is at the location of the sensor)
HeatSensorSetPoint	*IfcThermodynamic TemperatureMeasure*	The temperature value to be sensed.
HeatSensorRange	*IfcThermodynamic TemperatureMeasure* • LowerBound: variable • UpperBound: variable	The upper and lower bounds for operation of the temperature sensor.
HeatSensorAccuracy	*IfcThermodynamic TemperatureMeasure*	The accuracy of the sensor.
TimeConstant	*IfcTimeMeasure*	The time constant of the sensor.

Fig. 3: The IFC 2x2 *Pset_SensorTypeHeatSensor* property set (adapted from ref. [17])

PropertySet Name	*Pset_SensorTypeFireSensor*
Applicability	*IfcSensorType* entity.
Applicable Type Value	*FIRESENSOR*
Definition	A device that senses or detects the presence of fire.

Property Definitions:

Name	Data Type	Definition
FireSensorSetPoint	*IfcThermodynamic TemperatureMeasure*	The temperature value to be sensed to indicate the presence of fire.
AccuracyOfFireSensor	*IfcThermodynamic TemperatureMeasure*	The accuracy of the sensor
TimeConstant	*IfcTimeMeasure*	The time constant of the sensor.

Fig. 4: The IFC 2x2 *Pset_SensorTypeFireSensor* property set (adapted from ref. [17])

BRANZFIRE requires the optical density characteristics that will activate the alarm which can be defined as a specified optical density or using built-in sensitivity levels appropriate to AS1603.2 [18]. BRANZFIRE also accounts for the time delay for smoke entry into the detection chamber. The *Pset_SensorTypeSmokeSensor* property set includes the (apparently inaccurately named) *PressureSensorSetPoint* property which could be used to define the activation optical density and the *TimeConstant* property which could be used to determine the entry delay. The *Pset_SensorTypeSmokeSensor* property set has the potential for expansion since it does not specify the type of smoke sensor although this is not specifically required by BRANZFIRE.

IFC 2x2 also provides the *Pset_ SensorTypeGasSensor* property set (Fig. 6) which would allow for the inclusion of fire detection by CO or other suitable combustion product through the *GasDetected* property. The property set is similar to those for other forms of fire detection but does not include a *CoverageArea* property. Since the current version of BRANZFIRE does not allow for detection by combustion gases, mappings are not applicable.

PropertySet Name	*Pset_SensorTypeSmokeSensor*
Applicability	*IfcSensorType* entity.
Applicable Type Value	*SMOKESENSOR*
Definition	A device that senses or detects smoke.

Property Definitions:

Name	Data Type	Definition
CoverageArea	*IfcAreaMeasure*	The floor area that is covered by the sensor (typically measured as a circle whose centre is at the location of the sensor)
PressureSensorSetPoint	*IfcPositiveRatioMeasure*	The smoke concentration value to be sensed.
SmokeSensorRange	*IfcPositiveRatioMeasure* • LowerBound: 0 • UpperBound: variable	The upper and lower bounds of smoke concentration for operation of the smoke sensor.
AccuracyOfSmokeSensor	*IfcPositiveRatioMeasure*	The accuracy of the sensor
TimeConstant	*IfcTimeMeasure*	The time constant of the sensor.
HasBuiltInAlarm	*IfcBoolean*	Indicates whether the smoke sensor is included as an element within a smoke alarm/sensor unit.

Fig. 5: The IFC 2x2 *Pset_SensorTypeSmokeSensor* property set (adapted from ref. [17])

PropertySet Name	*Pset_SensorTypeGasSensor*
Applicability	*IfcSensorType* entity.
Applicable Type Value	*GASSENSOR*
Definition	A device that senses or detects gas.

Property Definitions:

Name	Data Type	Definition
GasDetected	*IfcLabel*	Identification of the gas that is being detected.
GasSensorSetPoint	*IfcPositiveRatioMeasure*	The gas concentration value to be sensed.
GasSensorRange	*IfcPositiveRatioMeasure* • LowerBound: 0 • UpperBound: variable	The upper and lower bounds of gas concentration for operation of the gas sensor.
AccuracyOfGasSensor	*IfcPositiveRatioMeasure*	The accuracy of the sensor
TimeConstant	*IfcTimeMeasure*	The time constant of the sensor.

Fig. 6: The IFC 2x2 *Pset_SensorTypeGasSensor* property set (adapted from ref. [17])

4.5 Smoke Control

IFC 2x2 includes a wide range of property sets applicable to HVAC systems through the *IfcHvacDomain* layer. These property sets include those appropriate to fans, ducts, heating and cooling systems and many other components. For fans the *Pset_FanTypeCommon* includes a number of general properties that are not specifically applicable to smoke control and BRANZFIRE mapping. However IFC 2x2 includes a property set for smoke control systems in the *Pset_FanTypeSmokeControl* property set (Fig. 7).

Additional properties for fans are also available through the *Pset_FlowMoving-DeviceFan* property set and specifically the *ApplicationOfFan* property can be used to indicate whether the fan type is *SUPPLY*, *EXHAUST* or has other applications.

PropertySet Name	*Pset_FanTypeSmokeControl*
Applicability	*IfcFanType*
Definition	Smoke control attributes of fan participating as part of a smoke control system.

Property Definitions:

Name	Data Type	Definition
OperationalCriteria	*IfcTimeMeasure*	Time of operation at maximum operational ambient air temperature.
MaximumDesignTemperature	*IfcThermodynamic TemperatureMeasure*	Maximum design operational temperature.
SmokeControlFlowrate	*IfcVolumetricFlowRate Measure*	Flowrate of fan while operating as a part of the smoke control system.

Fig. 7: The *Pset_FanTypeSmokeControl* property set (adapted from ref. [17])

BRANZFIRE allows a single fan to be associated with each room. The BRANZFIRE input parameters for mechanical ventilation are the flow rate, fan start time, cross-fan pressure limit, fan elevation, whether the fan is extracting or pressurising the space and if a fan curve should be used. The flow rate and air flow direction can be derived from the *SmokeControlFlowrate* and *ApplicationOfFan* properties respectively. The elevation of the fan can be determined through the geometry of the space but other parameters would need to be specified by the BRANZFIRE user.

Dampers are also defined in the IFC 2x2 *IfcHvacDomain* and in terms of fire engineering, they contribute to the fire resistance rating and smoke containment of a structure. Dampers are specified using the *IfcDamperType* entity which is a sub-type of the *IfcFlowControllerType* entity. IFC 2x2 defines three types of damper and are described as [17]:

- *FIREDAMPER*: Used to prevent the spread of fire for a specified duration.
- *SMOKEDAMPER*: Used to prevent the spread of smoke.
- *FIRESMOKEDAMPER*: Combination fire and smoke damper used to prevent the spread of fire and smoke.

There are no provisions to include dampers in BRANZFIRE and the details of the associated property sets are not included here.

4.6 Material Properties

4.6.1 Fire resistance

In addition to the material fire properties associated with structural elements, IFC 2x2 defines material fire properties in two other property sets as shown in Table 4. The *Pset_CoveringCommon* property set is associated with the *IfcCovering* entity which is used to specify an element which covers some part of another element and is fully dependent on that other element. Definitions for *Pset_CoveringCommon* follow those given for structural elements.

Table 4: IFC 2x2 material fire properties and associated entities

Property set definition and associated IFC entity	Property name and data type	Definition
Pset_CableSegmentType ConductorSegment (*IfcCableSegmentType*)	*IsFireResistant* (*IfcBoolean*)	Indicates whether sheath is fire resistant.
Pset_CoveringCommon (*IfcCovering*)	*FireRating* (*IfcLabel*)	Fire rating for this object.
	FlammabilityRating (*IfcLabel*)	Flammability rating for this object.
	Combustible (*IfcBoolean*)	Indicates whether object is made from combustible material.
	SurfaceSpreadOfFlame (*IfcLabel*)	Indication of surface flame spread.

4.6.2 Fire growth

For a large majority of fire simulation software tools it is necessary to identify the material properties related to the ignition and burning of building contents and linings. In BRANZFIRE burning items are characterised by a rate of heat release curve and the spread of fire over room linings can be determined from material properties. For fires involving linings, BRANZFIRE requires the material properties of the lining be specified plus an associated cone calorimeter data file [9]. Material properties held by the BRANZFIRE thermal properties database are the material description, thermal conductivity, specific heat, density, emissivity, minimum temperature for spread, flame spread parameter, heat of combustion, soot yield, water yield and carbon dioxide yield.

IFC 2x2 defines a number of material property entities which are sub-types of an *IfcMaterialProperties* entity. These sub-types contain related collections of properties that includes mechanical, thermal, optical and several others. For mapping to the BRANZFIRE thermal database, density is provided in *IfcGeneralMaterialProperties* entity; and heat capacity and thermal conductivity in *IfcThermalMaterialProperties* entity. IFC 2x2 also defines an *IfcProductsOfCombustionProperties* sub-type with the following attributes defined for the entity:

- *SpecificHeatCapacity* - Specific heat of the products of combustion, J/kg K.
- *N20Content* - Nitrous oxide content of the products of combustion.
- *COContent* - Carbon monoxide content of the products of combustion.
- *CO2Content* - Carbon dioxide content of the products of combustion.

Apart from *SpecificHeatCapacity*, each attribute is measured in weight of combustion product per unit weight of material. Finally, IFC 2x2 has an *IfcFuelProperties* sub-type which includes properties that specify the amount of energy released by a fuel when completely burned, the combustion temperature of the material and the carbon content ratio. The *IfcProductsOf CombustionProperties* and *IfcFuelProperties* sub-types are described in the IFC documentation [17] as being those properties "typically used within the context of building services and flow distribution systems". Since they are not intended for a fire engineering domain they have limited applicability for fire simulation software and are not considered relevant to BRANZFIRE.

In order to identify rate of heat release characteristics of an item it is clear that the current property specifications of IFC 2x2 cannot be used. Since the rate of heat release is a specialised aspect of the fire engineering domain, it would not be expected to be included in a general product model such as the IFC Model. Instead a transformation that allows the creation of a new property set (provisionally referred to as *Pset_FurnitureHeatRelease*) from the FireBaseXML database schema [19] has been created (Fig. 8). The addition of a *Pset_FurnitureHeatRelease* property set to an item may also provide a means to identify the location of the fire which is relevant to several geometric inputs required by BRANZFIRE such as the radial distance between a sprinkler and a fire.

4.6.3 Glazing

BRANZFIRE has the capability to predict when glass breaks [11] and this procedure requires a number of properties for the glass to be supplied. Required properties are the glass thickness, thermal conductivity, thermal diffusivity, Young's modulus, fracture stress, shading depth, thermal expansion coefficient and optionally the distance to the flame.

PropertySet Name	*Pset_FurnitureHeatRelease*

Property Definitions:

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

Fig. 8: Proposed *Pset_FurnitureHeatRelease* property set

PropertySet Name	*Pset_DoorWindowGlazingType*
Applicability	*IfcDoor*, *IfcWindow* entity.
Definition	Properties common to the definition of the glazing component of occurrences of *IfcDoor* and *IfcWindow*, used for thermal and lighting calculations.

Property Definitions:

Name	Data Type	Definition
GlassLayers	*IfcCountMeasure* • Default Value: 2	Number of glass layers within the frame.
GlassThickness1	*IfcPositiveLengthMeasure*	Thickness of the first (inner) glass layer.
GlassThickness2	*IfcPositiveLengthMeasure*	Thickness of second (intermediate or outer) glass layer.
GlassThickness3	*IfcPositiveLengthMeasure*	Thickness of the third (outer) glass layer.
FillGas	*IfcLabel*	Name of the gas by which the gap between two glass layers is filled. It is given for information purposes only.
GlassColor	*IfcLabel*	Colour (tint) selection for this glazing. It is given for information purposes only.
IsTempered	*IfcBoolean*	Indication whether the glass is tempered or not.
IsLaminated	*IfcBoolean*	Indication whether glass is layered with other materials.
IsCoated	*IfcBoolean*	Indication whether glass is coated with a material.
IsWired	*IfcBoolean*	Indication whether the glass includes a contained wire mesh to prevent break-in.
Translucency	*IfcPositiveRatioMeasure*	Fraction of the visible light that passes the glazing at normal incidence. It is a value without unit.
Reflectivity	*IfcPositiveRatioMeasure*	Fraction of the visible light that is reflected by the glazing at normal incidence. It is a value without unit.

Fig. 9: *Pset_DoorWindowGlazingType* property set (adapted from ref. [17])
(thermal and solar transmittance properties not shown)

Glazing properties are available in the IFC Model within *IfcSharedBldgElements* interoperability layer through a *Pset_DoorWindowGlazingType* property set (Fig. 9) in which only the *GlassThickness* properties are relevant as a mapping to BRANZFIRE. Further material properties may be obtained through the *IfcMaterialProperties* entity sub-types, specifically the thermal conductivity from the *IfcThermalMaterialProperties* entity; and the thermal expansion coefficient and the Young's modulus from the *IfcMechanicalMaterial Properties* entity. The distance to the flame may be determined if the location of the fire can be identified such as by the addition of a *Pset_FurnitureHeatRelease* property set to an item.

5. CONCLUSIONS

The latest version of the IFC Model supports fire engineering through a number of property sets defined in various places. This paper has noted some areas where enhancements and extensions to these property sets would be beneficial to fire engineers wishing to use the IFC Model as a source of input data into fire simulation software. It is only through the use of the IFC Model that feedback can be provided to the IFC developers so that they can enrich the fire engineering content of model.

This paper shows that mappings between the IFC model and the BRANZFIRE fire simulation software can be identified, as summarised in Fig. 10, and these mappings are likely to be appropriate for other fire simulation tools. Progress is already underway, building on the earlier work described elsewhere [20], to code the mappings described in this paper into a software tool that would allow the exchange of IFC files with BRANZFIRE and to extend the mappings to other fire simulation software tools.

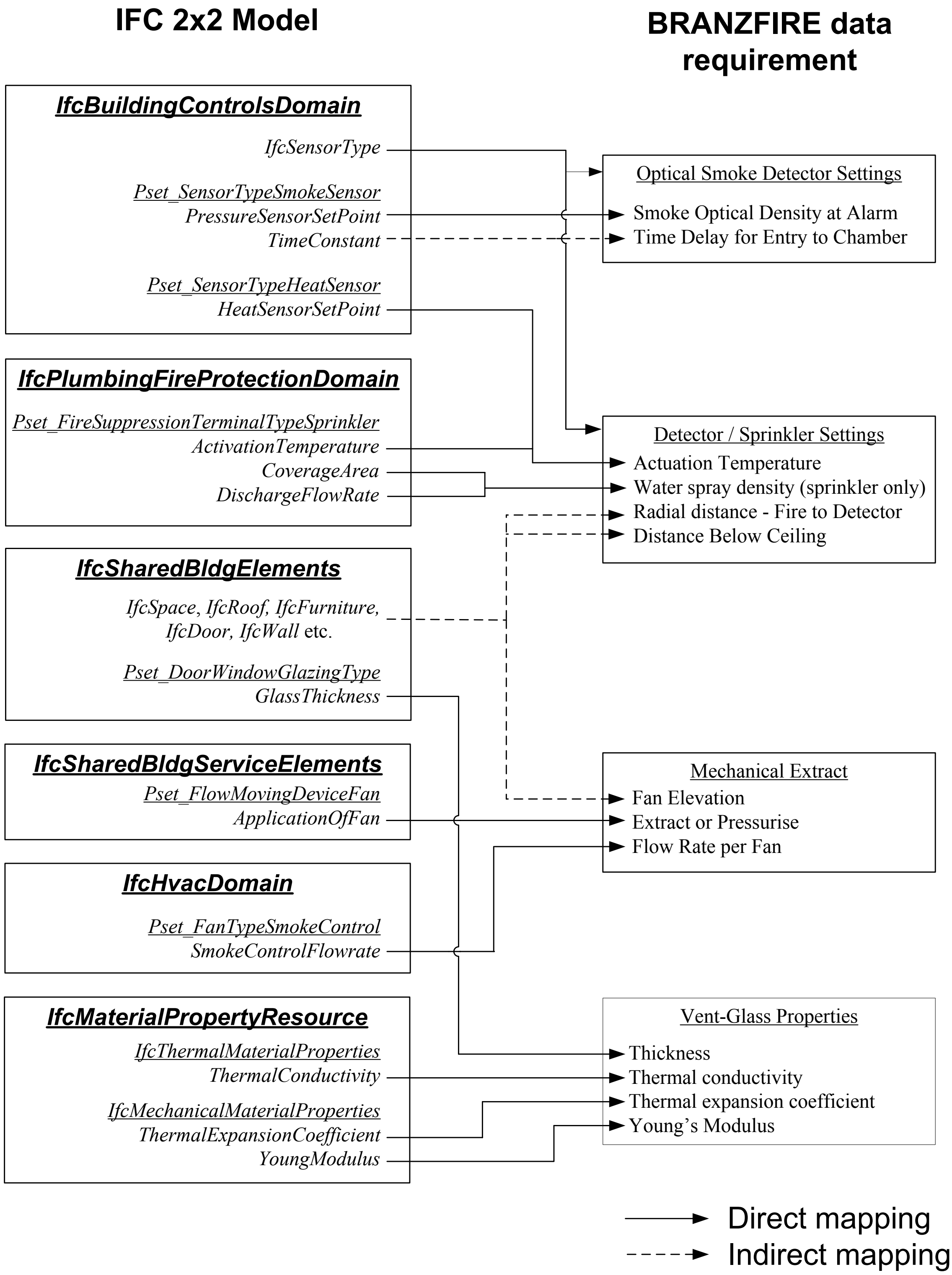

Fig. 10: Summary of mapping from IFC 2x2 to BRANZFIRE

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