Supplementary Material for Building Information Modelling for performance-based Fire Safety Engineering analysis – A strategy for data sharing

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The broad input data categories required for fire and evacuation modelling as part of performance-based Fire Safety Engineering (FSE) analysis, are shown in Table S1. Similarly, Table S2 provides information about the broad data output from fire and evacuation modelling. Further information related to these tables is also included. Also, selected attributes with description of the preliminary Fire and Evacuation Simulation output database schema are included in Table S3.

Table S1. Input data categories for fire and evacuation modelling tools and support in BIM

Data category	Subcategory	Fire modelling		Evacuation modelling		Support in BIM
		CFD	**Zone**	**Simplified***	**Advanced***	
Building Geometry	Basic building components (e.g. Walls)	Yes	Yes[1]	Yes	Yes	Yes
	Vents (e.g. Doors and windows)	Yes	Yes	Yes	Yes	Yes
	Fire safety related information (e.g. location of fire protection components and systems, load bearing indication for walls, etc.)	Yes[2]	Yes[2]	Yes[2]	Yes[2]	Yes
Material Properties	Thermo-physical properties of building structural components, fire rating indication, etc.	Yes	Yes	No	No	Yes
Smoke detection, warning and management	Fans, alarms and sprinklers activation situation	Yes	Yes	Yes[3]	Yes[3]	Yes

Data category	Subcategory	Fire modelling		Evacuation modelling		Support in BIM
		CFD	Zone	Simplified*	Advanced*	
Building Usage	Fuels i.e. burnable items/fire sources in the building, including furnishings, coatings, wiring producing fire effluent. Hazard releases not related to fire, e.g. toxic gas release. Building components (e.g. paints/coatings) may passively absorb hazards such as HCl	Yes	Yes	No	No	Some support
	Obstacles/furniture in the building	Yes	No	No[4]	Yes	Yes
	Number and distribution of occupants	No	No	Yes[4]	Yes	Yes
	Occupants' characteristics and behaviour	No[5]	No	No[4]	Yes	No
	Escape routes	No	No	Yes	Yes	Some support
	Signage	No	No	No[6]	Yes	Yes
	Building occupancy at day/night time hours	Yes[7]	Yes[7]	Yes	Yes	Some support
Other Considerations	Windows/Door failure changes ventilation	Yes	No	Yes	Yes	Some support
	Leakages	Yes	Yes	No	No	No
	Behaviour of the components (e.g. alarm activation conditions)	Yes	Yes	No	No	Some support

[*] ***Simplified:*** *hand calculations, simple flow models and coarse network models.* ***Advanced:*** *fine network and continuous models.*

[1] *The components like stairs and lifts are not included in Zone Models.*

[2] *The CAD file may contain the location of fire protection components and systems, but this would be very limited, if present at all, and open to interpretation by the viewer.*

[3] *Currently, only alarm to indicate pre-movement times.*

[4] *For Simplified approach, this is difficult to specify as the focus is on flows not individuals and precise location within a room or zone cannot be specified.*

[5] *Usually neglected but can have an impact (e.g. opening door to pressurised stairs).*

[6] *Not generally represented in Simplified approach.*

[7] *CFD/Zone modelling does not generally use the building occupancy though it may have some implications for where hazard data is needed for export.*

Table S2. Output data categories for fire and evacuation modelling tools

Data category	**Fire modelling**		**Evacuation modelling**		**Support in BIM**
	CFD	**Zone**	**Simplified***	**Advanced***	
Fire simulation data (e.g. Smoke and heat distribution)	Yes	Yes[1]	No	No	No[4]
Time to flashover	Yes[2]	Yes[2]	No	No	
Output of sprinkler and fire detector activation time	Yes	Yes[3]	No	No	
Component usage details (e.g. Usage of exits)	No	No	Yes	Yes	
Overall results (e.g. number of people safely out and fatalities/casualties)	No	No	No[5]	Yes	
Individual occupant level details (e.g. response time, distance travelled)	No	No	No[5]	Yes	

[*] ***Simplified:*** *hand calculations, simple flow models and coarse network models.* ***Advanced:*** *fine network and continuous models.*

[1] *Limited to results in layers – implications for the analysis of population exposure.*

[2] *This may or may not be accurately determined by the model. Certain model and sub-model combinations will not be able to predict this.*

[3] *Often limited to simple trigger values as convective flows are not computed.*

[4] *Some BIM packages, such as Revit, do provide options to add custom data sets to any element. However, there is no explicit support in BIM IFC for capturing the fire and evacuation modelling generated output data.*

[5] *For Simplified approach, it is difficult to identify unique individual details such as fatalities or casualties or distance travelled, etc as individuals are not represented.*

The following are important further considerations and observations including any deficiencies related to Table S1 and Table S2:

- Comparisons of evacuation modelling tools [1, 2] have highlighted significant differences in their capabilities. Similarly, there are significant differences in the capabilities of fire modelling tools and therefore not all of them support the level of data input and output mentioned in Table S1 and Table S2. Furthermore, currently acquiring input data mentioned in Table S1 and then utilising it in fire and evacuation modelling tools requires a significant amount of manual data input.
- The fire strategy may involve active (e.g. sprinklers, smoke extraction/venting, etc.) and passive (e.g. compartmentation, material choices, etc.) fire safety systems but also management systems and procedures (e.g. use of fire marshals, training, housekeeping, etc.) and so has implications to the future safe operation of the building.
- Several evacuation modelling tools support the use of fire data to understand population exposure to fire effluents in evacuation simulations [1, 2]. However, most of the currently available evacuation models do not typically allow population actions to impact fire evolution. However, two-way coupling capabilities, where building occupants can interact with the evolution of the simulated fire development, are currently being developed [3, 4, 5]. The nature of this interaction allows occupants to open or close doors thereby changing fire compartmentation and/or impacting stair pressurisation, firefighting and/or smoke management.
- For fire modelling, the level of data input requirements also depends on the nature of the fire model. CFD based models require considerably more detailed data than do Zone models. The data generated by fire modelling tools can vary due to the availability of different types of models and the level of sophistication that they offer. For evacuation modelling, the level of acceptable data input varies depending on the particular evacuation model. For example, the simpler models only require room connectivity and prescribed flow rates between compartments.
- The location of any fire protection components/systems (e.g. sprinklers and alarms), as well as an understanding of the behaviour of the components, is required. For instance, the pattern of sprinkler activations due to smoke or heat detection, the flow rate, the droplet spread pattern and droplet size/trajectories for sprinklers. It is often also necessary to understand the geometry of the component (e.g. a smoke or temperature sensor) because this can have an impact on the activation of various fire safety systems (or timing of the first alert) as determined in the fire modelling simulation.
- There are two distinct aspects of fire hazards. In fire modelling, the sources of toxic species must also be specified, which are generally estimated from the type of fuel and the likely burning conditions; whilst the hazard spread is computed by the fire modelling software.

Conversely, the evacuation modelling software requires as input the time and spatially varying concentration data of all the hazardous fire effluents and toxic species (as computed by the fire modelling software).

- Temporal changes such as when and/or under what conditions fans, alarms and sprinklers are activated are important inputs. The temporal data also applies to the population, i.e. will there be differences in the occupants, occupant behaviour, building occupancy and room usage based on the time of day, a particular day of the week or time of year?
- Consideration is also given to the issue of potential failures, which applies primarily to doors and windows. For windows, the time and mode of failure is likely to have a significant impact on the fire development due to changed ventilation conditions. The issue of potential component failure is a highly challenging and complex issue that is difficult to address in a standard way that is compatible with fire modelling. However, it is proposed that the database will at a minimum aim to record the likely failure time, mode of failure and causative conditions and how these should be determined.
- Sometimes, wall and floor surface coatings (e.g. paint and carpets/floor-coverings) can be important due to their effect on the release or absorption of toxic species. This is a relatively uncommon consideration but for completeness, it is mentioned here and is becoming more important due to the increasing use of eco-friendly building materials that are better insulators, but also potentially more flammable (e.g. recycled materials used in building insulation).
- Other aspects of the design which are needed include smoke management systems that may be dynamically activated, such as fans; smoke curtains; smoke extraction systems; and automatic or manually operated louvres/vents. Furthermore, air leakages (e.g. gaps under and around doors) and through walls and water supply characteristics (or smoke extract fan characteristics) may also be required.
- There is support in BIM for building component information such as its location, material and further details that can be provided by the manufacturer. It is proposed that a requirement for using appropriate meta tags could facilitate searches for such additional data within manufacturer supplied textual data about components.
- The property sets for objects in IFC can be utilised to capture some building usage related information. For instance, for space within a building, property sets such as *Pset_SpaceFireSafetyRequirements* (Single value properties: *FireRiskFactor, FireExit, SprinklerProtection, SprinklerProtectionAutomatic* and *AirPressurization*) and *Pset_SpaceOccupancyRequirements* (Single value properties: *OccupancyType, OccupancyNumber, OccupancyNumberPeak, OccupancyTimePerDay, AreaPerOccupant, MinimumHeadroom* and *IsOutlookDesirable*) can be used.

Table S3. Preliminary Fire and Evacuation Simulation output database schema with selected attributes and description

Entities	Attributes	Brief description
Scenario	ScenarioName, ScenarioDescription, AssumptionsMade	Basic details of scenario(s) identified for analysis.
FireEvacZone	FireEvacZoneName	List of zones for the identified scenario.
Level	LevelName	List of levels/floors.
Exit	ExitName	List of Exits.
EvacuationSimulation	EvacSimStartTime, EvacSimEndTime, TotalNumOfSimPeople, NumOfPeopleOut, NumOfFatalities	Some key overall information of the evacuation simulations which were executed for the identified scenario(s) is captured by this entity.
SimulatedOccupant	Gender, Weight, DistanceTravelled, ResponseTime	Individual simulated occupant details are captured by this entity.
EvacSimLevelPerformance	NumberStarted, LastExitTime	The overall usage of level during executed simulations is captured by this entity.
EvacSimExitPerformance	TotalNumberUsedIt, FirstOutTime, LastOutTime	The overall usage of exits during executed simulations is captured by this entity.
FireSimulation	FireSimStartTime, FireSimEndTime,	Some overall information of the fire simulation which was executed for the identified scenario(s) is captured by this entity.
FireSimZoneHazard	UpperValue, LowerValue, TimeInterval	The details of hazards at a specific time for specified fire zone during a simulation.
HazardType	HazardName, HazardDescription	The type of hazard (e.g. CO).

Note: This preliminary database schema only covers an identified minimum set of fire and evacuation simulation outputs that were required for the prototype and furthermore, only using the identified software. As part of the proposed buildingSMART project, this analysis will be expanded and will be an ongoing data enrichment activity to cover both the common set of capabilities and outputs of the available FSE software as well as providing sufficient data for the diverse requirements from all the likely use cases and applications for FSE simulation results.

References

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