INDUSTRY INSIGHT

buildingSMART International

openBIM for Occupant Movement Analysis Industry Report

A Perspective from the Building Room

Case 1: Evacuation Analysis – RIBA stages

Case 2: Evacuation Analysis – International

Case 3: Circulation Analysis – International

CONTENTS

1. Summary

The safety and comfort of building occupants are of vital importance. For building design and compliance checking concerning occupants' safety in buildings, prescriptive codes are usually used. However, for more complex buildings the prescriptive rules are not always applicable, and therefore, a performance-based approach (engineering approach) is employed. This performance-based approach to fire safety which is also known as Fire Safety Engineering (FSE) utilizes either hand calculations or computer model simulations (using simulation tools) to determine whether the performance indicators are fulfilled according to regulations and then in turn establish if a building is compliant.

Occupant Movement Analysis (OMA) includes aspects of non-emergency and emergency movement of people. Circulation modelling focuses on the non-emergency movement of people, whereas evacuation modelling as part of the FSE-based analysis focuses on the emergency movement of people. During the planning and lifecycle process of a building, circulation modelling plays an important role. It offers a deep insight into the building's functionality and capacity concerning occupants' flow and comfort, thus, improving space utilization and productivity. On the other hand, evacuation modelling is used to determine evacuation times and possible bottlenecks in the building's design. In short, OMA has an important role in establishing occupants' safety and comfort during the building lifecycle, particularly during the design phase.

The use of Building Information Modelling (BIM) is increasing significantly but for OMA the adoption is still relatively slow, which impedes the realization of potential BIM benefits such as mitigating risk and cost reduction. The goal of this paper is to provide an insight into how buildingSMART International (bSI) is adding support for OMA requirements in the IFC Model. Work was initiated to develop a Information Delivery Manual (IDM) for OMA that focuses on capturing the data requirements including key simulation results produced by the pedestrian modelling tools. This work will not only incorporate properties into the IFC Model to meet the common needs of OMA data exchange requirements for the modelling tools but in turn also enable an open, connected iterative workflow.

The following three broad use cases are presented in this paper to highlight the work which is currently underway:

1. Evacuation Analysis – based on The Royal Institute of British Architects (RIBA) stages.
2. Evacuation Analysis – International (non-country specific).
3. Circulation Analysis – International (non-country specific).

2. OMA and current issues

A high-level view of how OMA fits into the building lifecycle is shown in Figure 1. The phases shown in Figure 1 are based on research carried out by the International Fire Safety Standards (IFSS) Coalition [1]. As mentioned previously, OMA caters for both emergency and non-emergency movement of building occupants. Figure 1 highlights how the building's life cycle is framed within the regulations, codes and standards. The fire safety design strategy can adapt and change throughout this life cycle, however, it often has its most significant impact during the Design Phase. The building designer, such as the architect, often works in conjunction with a number of other experts to identify circulation and fire safety factors. During this design phase, the fire safety and circulation strategies will be considered, as shown in Figure 1, which will feed back into the design process. This is something that the BIM model should capture, which is currently lacking.

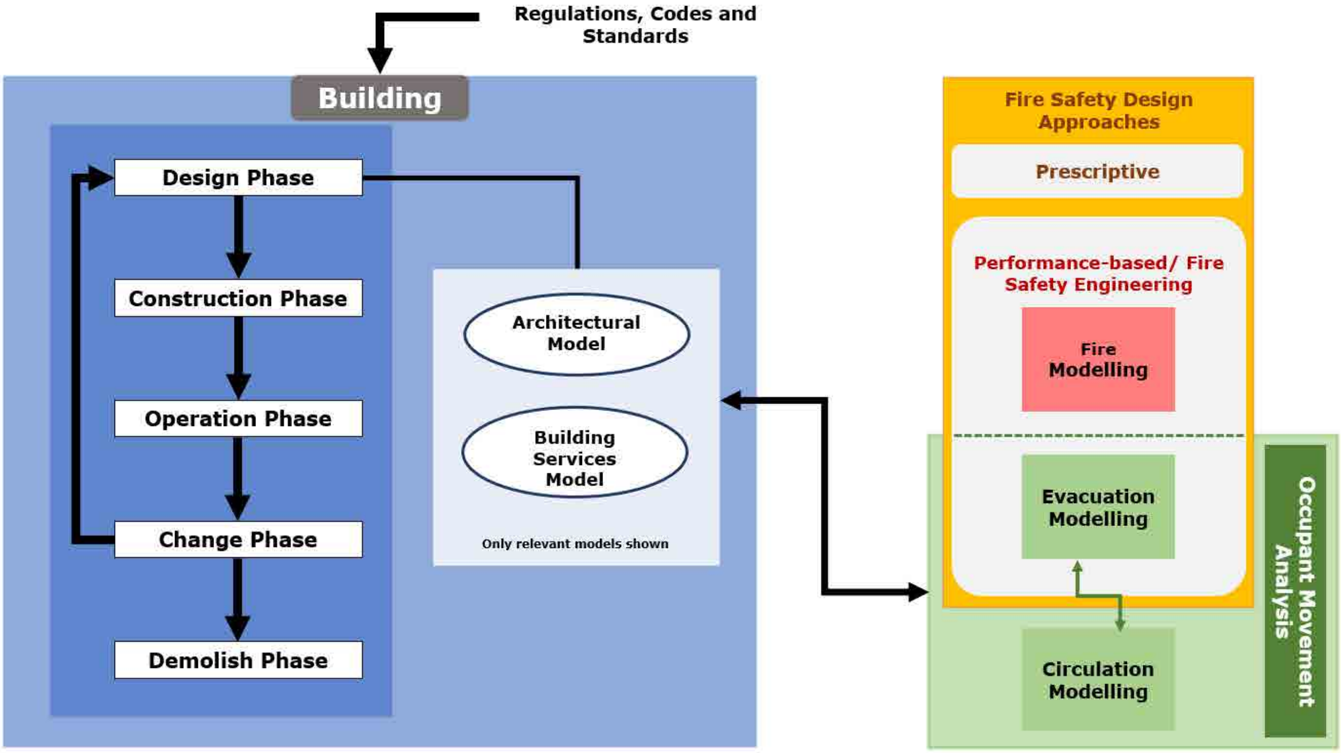

Figure 1. OMA in the building lifecycle

To analyze non-emergency movement concerning occupants' flow and comfort, circulation modelling is used. By using simulation tools, building capacity aspects are analyzed and optimized to establish procedures and processes related to building occupancy and use. This allows quick and affordable digital prototyping, avoiding costly planning errors, which could impact how people interact with the building and occupant revenue generation, for example, how customers may utilize a shop or airport. The fire safety design strategy cannot be performed in isolation, it must consider building use and function. For example, changes to the circulation strategy may impact the location and capacity of rooms and offices within the building. This, in turn, will impact emergency exit routes, which need to have the capacity to evacuate people safely and quickly. Both the circulation and fire safety strategy have an impact on the size, area and function of spaces, as well as staircases, lifts and doors. These are all structural elements, so a comprehensive BIM model needs to be able to identify that any changes to these components may invalidate the fire safety or occupant use strategies.

For a given building, FSE based analysis has to determine the Available Safe Egress Time (ASET), which needs to be greater than the Required Safe Egress Time (RSET) plus a suitable safety margin. ASET refers to the duration of time that elapses after the ignition of a plausible fire and before the presence of smoke, heat, and poisonous gases create untenable conditions which can be fatal to the occupants. The ASET is generally calculated by a Fire Engineer using computer models or hand calculations. On the other hand, RSET, commonly defined as the time required to complete the evacuation, is driven by human behavior. RSET is estimated either by hand calculations or, in more complex buildings, by computer simulation. Another approach is to use coupled fire and evacuation analysis, where the impact of fire hazards on the population is directly taken into consideration during the evacuation simulation and so RSET and ASET values are not explicitly determined. Although this approach is less common, it can provide more realistic results [2]. It should be noted that evacuations do occur for other reasons, such as an industrial hazard, gas leaks, floods, or as a precautionary measure, such as a suspicious item.

During building design, any data inconsistencies due to incorrect or missing information not only have serious implications on project costs and time but from the fire safety perspective, also an increased risk to life. Hence the requirement to establish a "golden thread of information" for fire safety through the use of BIM was identified as critical in the post-Grenfell Tower disaster review report by Hackitt [3]. Furthermore, the IFSS Coalition's "Decade of Action for Fire Safety 2022-2032", calls for a new framework to support audits, compliance checks and global standards [4]. However, there are a number of challenges that need to be addressed before OMA can be fully integrated into BIM, such as:

- No OMA specific data exchange is currently available.
- A relatively small number of OMA tools have support for IFC files, which is limited primarily to importing geometry.
- Lack of open and standard tools to connect OMA into the BIM workflow.
- Frequent data loss between the design and review stages.

There is a growing international interest in digitalization, and in terms of digital compliance checking, fire safety is becoming a key area for consideration. Therefore, interested parties are welcome to participate, as the work here on enhancing BIM standards can be seen as an opportunity to influence and harmonize the standards and practices that will impact building design and fire safety globally.

3. Approach

The OMA project team is developing an IDM to capture the required evacuation and circulation modelling information that can be directly employed by modelling tools, together with the capture of key simulation results. Currently, two bSI projects that are related to the OMA project have open calls for participation and are awaiting financial support to commence work. The first one is a proposed bSI Building Room FSE project focusing on bringing fire safety engineering aspects into BIM. The second one is a bSI Regulatory Room project focusing on the Regulatory Information Requirements. The relationship between these projects is illustrated in Figure 2.

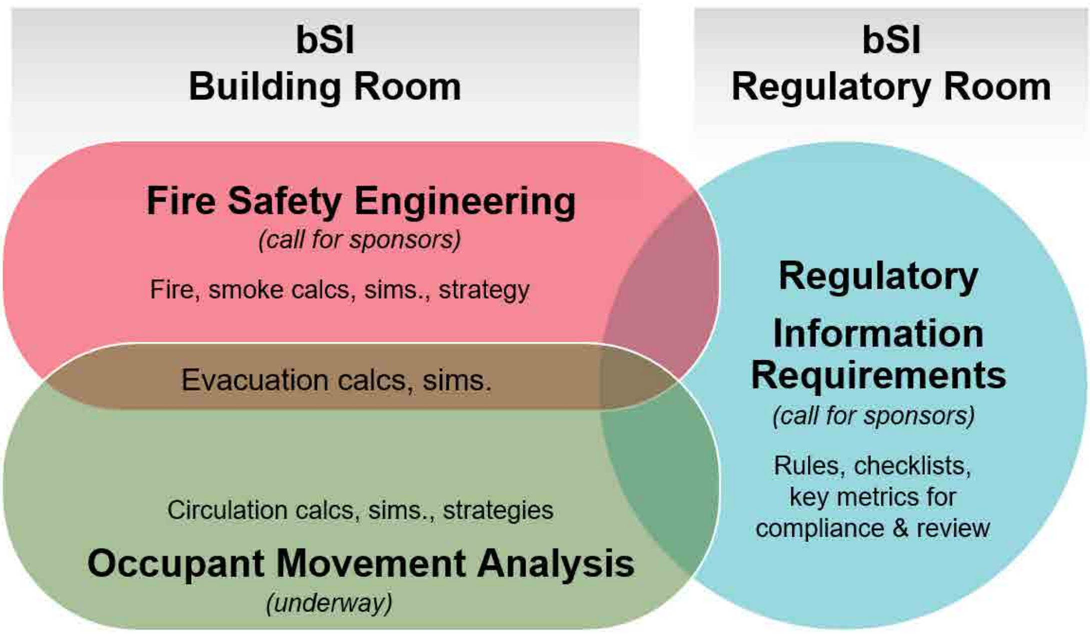

Figure 2. The link between the OMA project and other bSI projects

It should be noted that even though the OMA project is part of the bSI Building Room, the core aspects covered in it are relevant for other bSI rooms such as Airport, Infrastructure, Railway and Regulatory.

The OMA data exchange requirements for different occupancy types (Residential, Office, Health care, Educational, and Stadia) are currently being analyzed. The approach is to review data properties supported in multiple pedestrian modelling tools and generate a list of essential and desirable properties for OMA. The following three broad use cases will be discussed further in the next section, focused on the various building design phases. Each use case will cover all the above-mentioned occupancy types that have been identified:

1. Evacuation Analysis – based on the RIBA stages.
2. Evacuation Analysis – International (non-country specific).
3. Circulation Analysis – International (non-country specific).

The use cases' objectives are:

1. Identify the actors and stages involved in the design phase.
2. Identify the workflow for evacuation/circulation analysis.
3. Identify data exchange requirements to carry out evacuation/circulation analysis using modelling tools.
4. Identify current IFC support for data exchange and limitations, together with areas for improvement and extension.

For all three use cases, process maps have been produced with feedback from the expert panel, composed of an international team of academics and industrial partners. The work on identifying essential and desirable data properties for each occupancy type based on a review of multiple pedestrian modelling tools is currently ongoing. So far, a list of broad data categories has been produced and shown in Figure 3.

Input data					
		Circulation modelling		Evacuation modelling	
Main data category	**Subcategory**	**Simplified***	**Advanced***	**Simplified***	**Advanced***
Building Geometry	Basic building components (e.g. Walls)	Yes	Yes	Yes	Yes
	Vents (e.g. Doors and windows)	Yes	Yes	Yes	Yes
	Stairs, Escalators, Elevators	Yes	Yes	Yes	Yes
	Fire safety related information (e.g. location of fire protection components and systems, load bearing indication for walls, etc.)	No	No	Yes[1]	Yes[1]
Smoke detection, warning and management	Fans, alarms and sprinklers activation situation	No	No	Yes[2]	Yes[2]
Building Usage	Obstacles/furniture in the building	No[3]	Yes	No[3]	Yes
	Number and distribution of occupants	Yes	Yes	Yes[3]	Yes
	Occupants' characteristics and behaviour	No[3]	Yes	No[3]	Yes
	Escape routes	No	No	Yes	Yes
	Signage	No[4]	Yes	No[4]	Yes
	Building occupancy at day/night time hours	Yes	Yes	Yes	Yes
Other Considerations	Windows/Door failure changes ventilation	No	No	Yes	Yes

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

[1] 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.

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

[3] 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.

[4] Not generally represented in Simplified approach.

Figure 3. Broad categories for OMA data exchange requirements

4. Use Cases

4.1 Use Case 1: Evacuation Analysis – RIBA stages

Use Case 1 examines the stages involved in the UK RIBA guidelines to identify current UK fire safety practices and data exchanges performed during the building design phase. The UK was the first country to introduce the performance-based approach for fire safety and this is the reason why this use case was identified as essential.

The aim is to identify the FSE based workflow related to the evacuation design of a given structure based on the UK RIBA stages, focusing on the building design stages 2 (Concept Design), 3 (Spatial Coordination) and 4 (Technical Design). So far, for this use case, a process map has been produced (see Appendix A) while work on identifying data exchange requirements for different occupancy types (Residential, Office, Health care, Educational, and Stadia) is in progress.

4.2 Use Case 2: Evacuation Analysis – International

Use Case 2 examines evacuation analysis in a generic non-country specific way.

The aim is to identify generic workflow and data exchange requirements related to the evacuation design of a given structure. Within the scope of this work, feedback from international experts was obtained regarding approaches employed in multiple countries (e.g., Germany and the US). So far, for this use case, a process map has been produced (see Appendix B) while work on identifying data exchange requirements for different occupancy types (Residential, Office, Health care, Educational, and Stadia) is in progress.

4.3 Use Case 3: Circulation Analysis – International

Use Case 3 examines the circulation analysis and it is intended not to be country specific.

The aim is to identify generic workflow and data exchange requirements related to the circulation analysis aspects of building design. So far, for this use case, a process map has been produced (see Appendix C) while work on identifying data exchange requirements for different occupancy types (Residential, Office, Health care, Educational, and Stadia) is in progress.

5. Our Vision: Two-way data sharing

Currently, the data sharing between BIM authoring software and the pedestrian modelling tools has several limitations [5], for instance:

- No data exchange specification to support OMA specific data exchange for the pedestrian modelling tools.
- Only a limited number of pedestrian modelling tools have support for IFC file import, and support is usually limited to extraction of the building's geometry.
- The simulation results produced by the modelling tools are not explicitly captured in the IFC Model, which limits data sharing to a one-way process.

This one directional data flow results in a loss of data, effort and time. The work presented in this paper will address the data loss issues as well as offer opportunities to establish integrated two-way data sharing. This will be achieved by incorporating required OMA properties into the IFC Model to maintain design and analysis data in an open, connected digital workflow where calculations and reviews can be integrated into a "golden thread of information". This standardized and connected workflow will offer substantial savings regarding time and effort for practitioners and at the same time avoid data loss.

In terms of the data sharing, the data exchange specification for OMA work can potentially offer the following two options:

1. Two-way data sharing without an Add-in.
2. Integrated two-way data sharing through an Add-in.

5.1 Two-way data sharing without an Add-in

Shown in Figure 4, is a system that utilises IFC based file transfer to demonstrate two-way data sharing between a BIM authoring software and a pedestrian modelling tool.

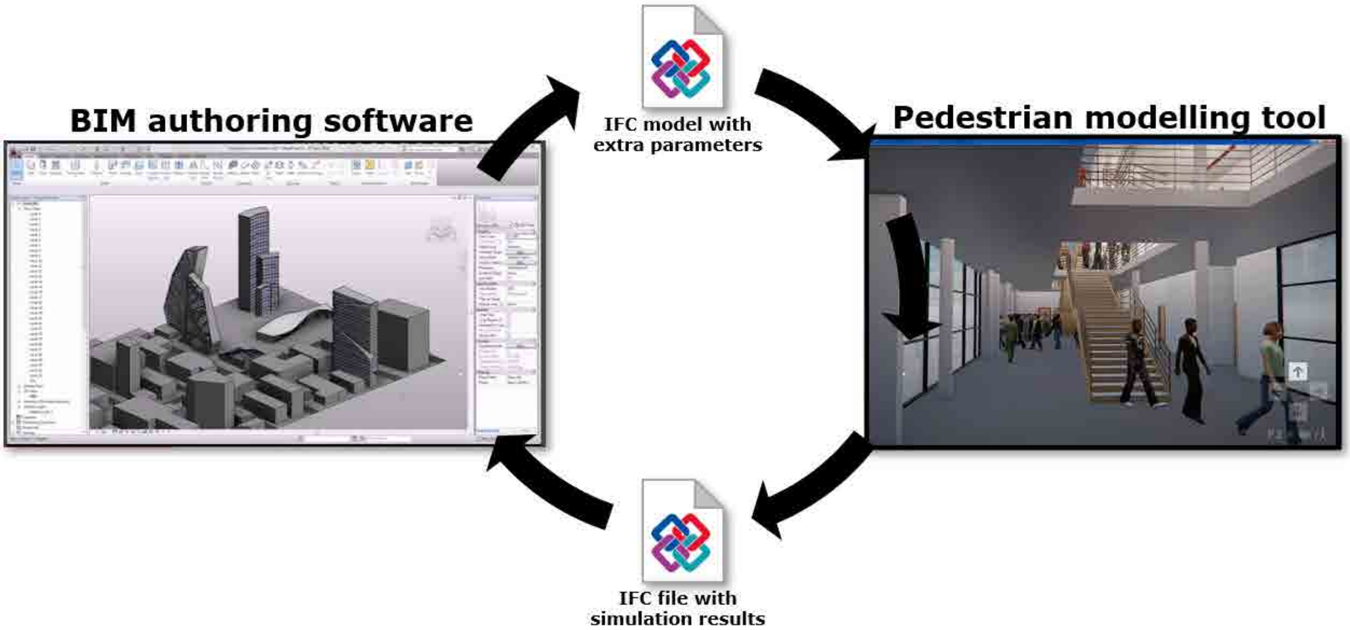

Figure 4. IFC file based two-way data sharing between BIM authoring software and pedestrian modelling software

The enhanced IFC file of the building model, which is based on the data requirements as specified in the IDM for OMA, is exported from the BIM authoring software. This IFC file is then imported into the pedestrian modelling tool and then the user setup and run the required simulations. The updated enhanced IFC file containing the key results of simulations is then exported from the pedestrian modelling tool and imported into the BIM authoring software to complete the integration with two-way data sharing.

5.2 Integrated two-way data sharing through an Add-in

Two-way data integration will enable a standardized and fully connected workflow for the practitioners and offers clear benefits in terms of time and effort saving. This can be achieved through an Add-in for the BIM authoring tool.

To demonstrate this type of workflow, a prototype Add-in has been developed as part of an MSc project at Lund University [6]. This prototype Add-in supports two-way data sharing between a BIM authoring tool (in this case Autodesk Revit) and an evacuation modelling tool (in this case Pathfinder). As shown in Figure 5, in this approach, an enhanced IFC file containing the required information for the evacuation modelling is exported from the BIM authoring tool which is then imported into the evacuation modelling tool. After the simulation results are produced by the evacuation modelling tool, they are then added to the updated IFC file and imported into the BIM authoring tool. The simulation results are then visualized directly in the BIM authoring tool by utilizing enhanced graphical features provided by the Add-in. If further changes are required then the cycle can be repeated until an acceptable solution has been reached.

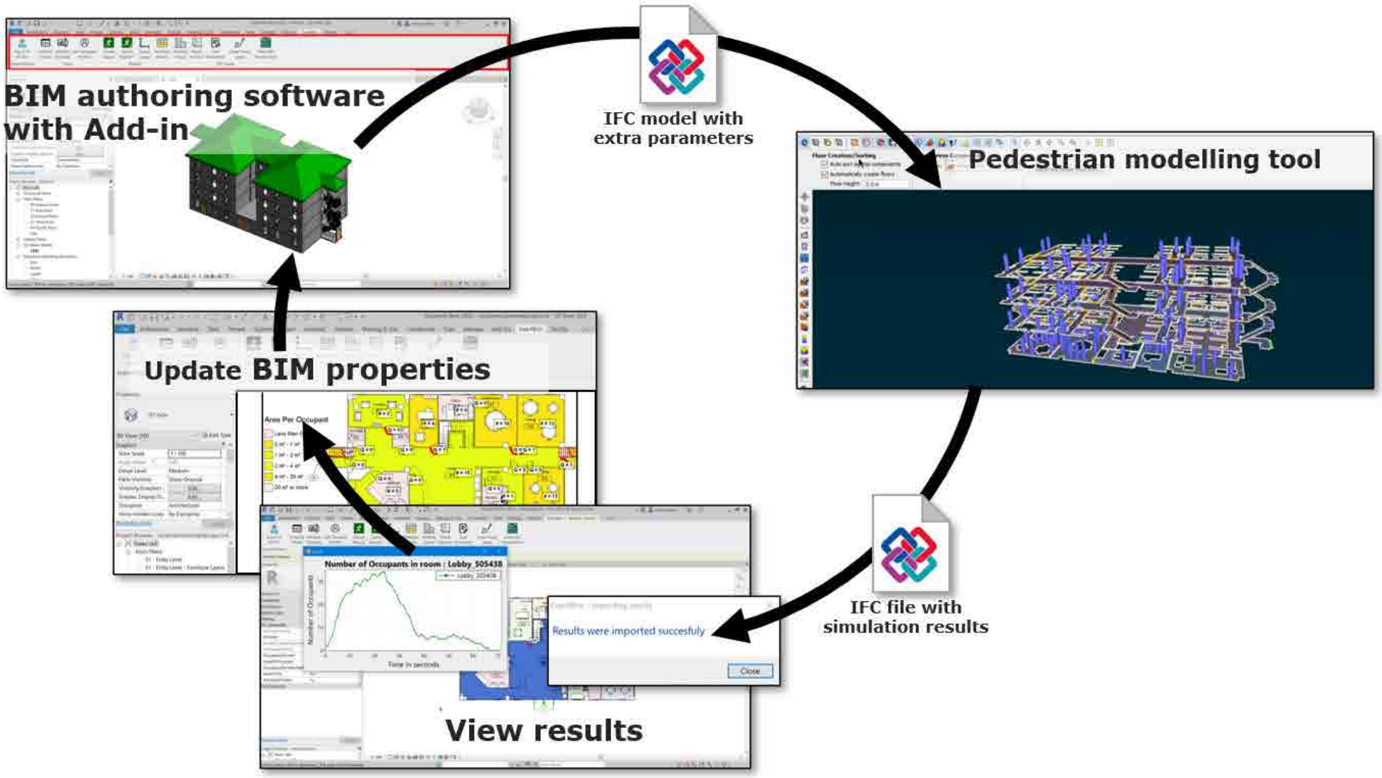

Figure 5. Two-way data sharing prototype Add-in

This two-way coupling approach will lead to several benefits. For instance, the following:

- Skills and tools portability and interoperability.
- Smart compliance checking and through-life assurance of building safety through change, occupancy/usage and refurbishment.
- Streamlining of working practices and cost savings.
- Move towards a plug and play BIM environment for diverse modelling support capabilities starting with OMA, but extending to other areas.

6. Potential benefits for the stakeholders

The data exchange specification development work on enhancing support for OMA in the IFC Model will offer several potential benefits for the stakeholder (e.g., Regulators, Fire Engineers, Owners/Clients, Construction Companies/Builders, Consultancy firms, etc.) producing a more robust plan. Some of the key benefits are summarized below:

1. Audit Trail: Information relating to the OMA process, including records of inputs, outputs, and assumptions.
2. Compliance Checking: Access to full information on OMA data and potentially facilitate automated compliance checking.
3. Decision Making: Preserves and tracks the information relating to the association between the OMA and the building's design, throughout the design process and life cycle.
4. Automation: Development of enhanced software tools to manage the OMA processes and smart building capabilities.
5. Safety: Ensure all stakeholders understand the logic relating to the OMA related design aspects.
6. Cost Savings: Identify OMA issues sooner to avoid costly changes later in the project.
7. Time Saving: Streamline the process of data sharing between stakeholders.

7. Next steps

This paper sets out to provide an insight into the work undertaken by bSI to support OMA. The current issues regarding the use of BIM to support OMA workflow, together with how the IDM for OMA project is aiming to address them are highlighted in the paper. In the first phase of the project, process maps of the three identified use cases have been produced. Also, broad categories of the required data exchange have been identified. The next phase of this project is currently underway, it will include the identification of specific data properties for each data category based on a review of multiple pedestrian modelling tools.

The ongoing effort presented in the paper will require support from various stakeholders to realize its full potential benefits.

8. References

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9. Acknowledgements

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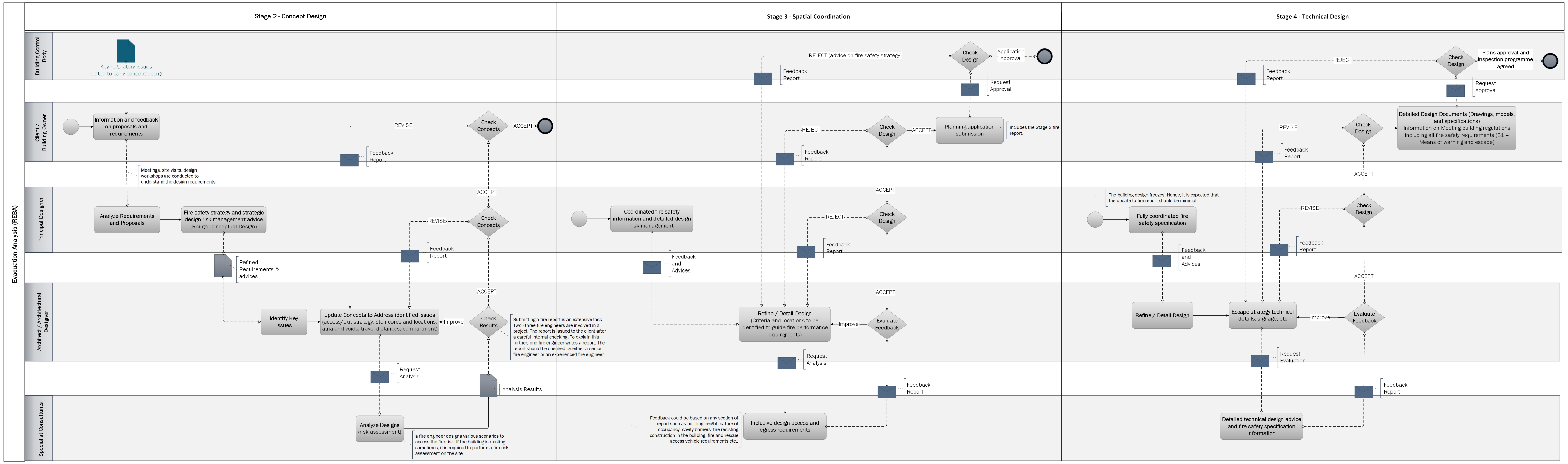
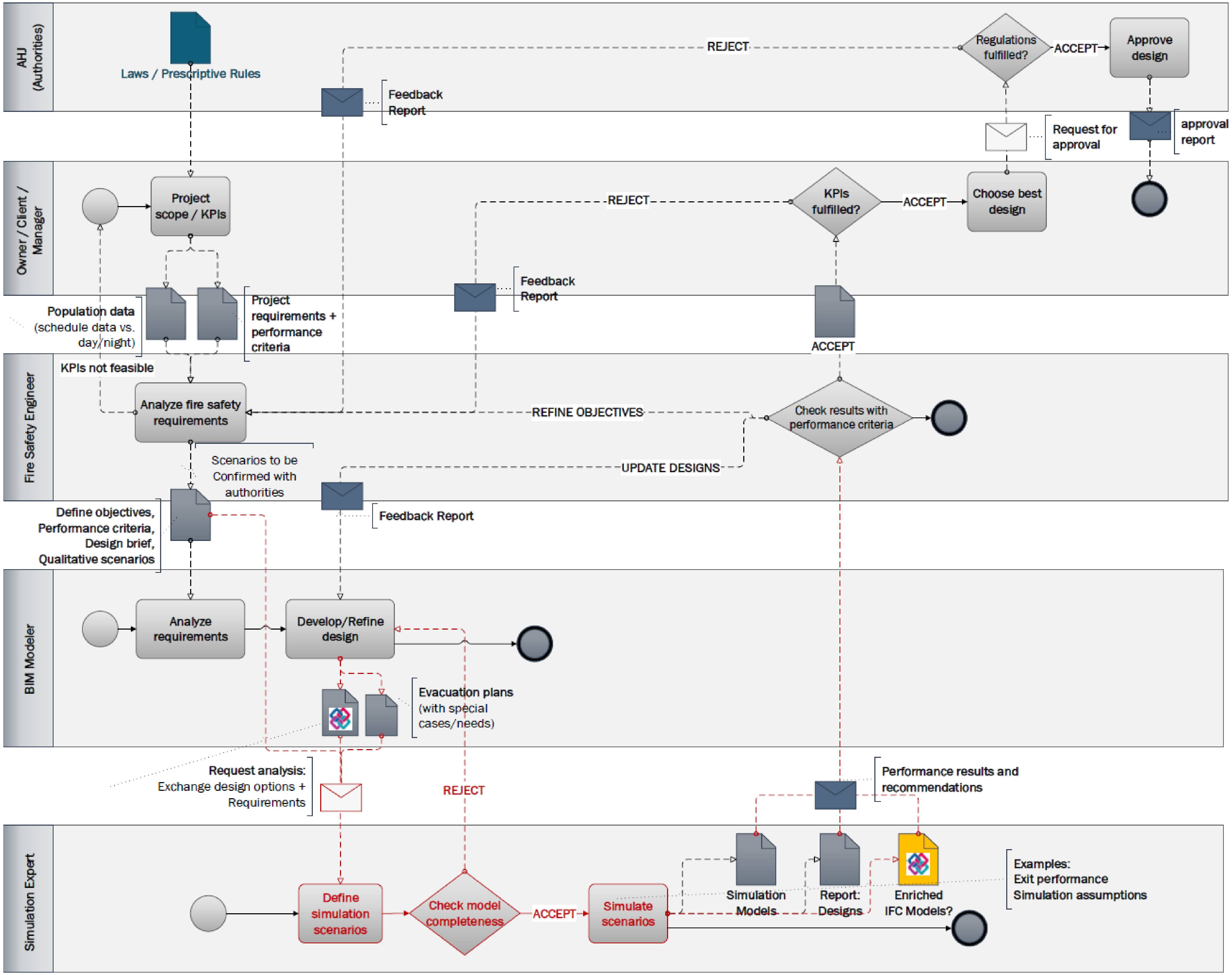
Appendix A: Process map of Use Case 1

The overall process in practice, actors and the key data exchange for **Use Case 1 Evacuation Analysis – RIBA stages focusing on stages 2, 3 and 4** are shown below:



Appendix B: Process map of Use Case 2

The overall process in practice, actors and the key data exchange for **Use Case 2 Evacuation Analysis – International** is shown below:



Appendix C: Process map of Use Case 3

The overall process in practice, actors and the key data exchange for **Use Case 3 Circulation Analysis – International** is shown below: