BIM-based tools for energy-efficiency renovations

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Introduction

According to the IEA, energy efficiency is the 'first fuel' and a key element in the transition to net zero and better energy security. In the 2030 Climate Target Plan, the EU has set ambitious targets to cut carbon emissions by 2030 by at least 55% compared to 1990 levels. With 75%–85% of existing dwellings standing in 2050, it is imperative to focus on renovating an ageing building stock. The current renovation rate is modest at ≈ 1.2%/year; this rate should increase to 3% or more if we hope to achieve these targets.

For many buildings, especially ones that existed before the digital era, digital documentation is scant or even non-existent. Achieving health and well-being benefits requires consideration of aspects beyond energy, such as comfort (thermal, visual, acoustic), life-cycle costs and recording of user preferences. Even though there is significant evidence of unintended consequences, an excellent evidence-based knowledge base of best (and worst) practices does not exist. Very often, there is no post-renovation evaluation to quantify the benefits of specific interventions. The renovation market is quite fragmented, with multiple stakeholders with different and often conflicting interests. The fragmentation is reflected in the communication and information exchanges between stakeholders. All these factors are exacerbated when analysing the *associated risks and costs, leading to reluctance to invest in energy renovation and* low renovation rates.

The whole renovation process should be improved and can benefit from increased use of digital engineering tools to support stakeholders throughout the renovation process of existing buildings, from project inception to delivery. Within the recently completed EU research project BIMERR[**1**], we have been developing an ICT-enabled Renovation toolkit to support a streamlined and improved approach to planning and delivering renovations and retrofits.

The primary aim of the BIMERR project is to deliver on this vision of the *Digital Twin* in the context of renovation. The term '*Digital Twin*' refers to the digital replica of physical assets, processes and systems. In residential renovation, the digital twin is the digital replica of a physical dwelling that is kept updated (i.e., not static) over time. It holds geometry, design, cost, schedule, material, energy, condition, and other data, across each stage of the project life cycle. Its purpose is to facilitate multi-stakeholder interactions, supporting all life cycle processes and making it possible to integrate domain-specific tools in support of decision-making. This can improve productivity and communication, improve quality, and help reduce implementation risks.

Approach

A Common Data Model is essential to ensure interoperability across tools and a seamless flow of information across software components and stakeholders. The BIMERR Data Model comprises the open BIMERR ontology[**2**] covering non-geometric domains, supplemented by a BIM (Building Information Model) model for geometry and geometry-related aspects. As part of the research undertaken within BIMERR, we have developed, deployed and demonstrated an ICT set of tools (see **Figure 1**) to support activities related to (i) digital building model creation, (ii) design support for renovation designers and (iii) construction work planning and workflow management.

Ensuring good quality data is critical. The BIM Management platform (a cloud-based tool) implements several approaches to data management that can support accelerating the (information) modelling process. The BIM models were created in the IFC (Industry Foundation Classes) to ensure better interoperability as per the ISO 16739 openBIM standard. We describe the process in the context of the demonstration sites that were part of the project.

Results

Shown in **Figure 2** is an example from one of the pilot sites. On the left is the building to be renovated (a residential block in Spain). To accelerate the BIM model's generation process, we explored two pathways: 1) perform an on-site survey and collect point cloud data. A Scan-to-BIM algorithm developed within the project can automate extracting a good quality BIM model from the point cloud data. When floor plans or other such information exists, modelling can happen within any BIM authoring tool.

We found that the approach of creating the models could vary significantly between BIM modellers; for this reason, we produced modelling guidelines to ensure

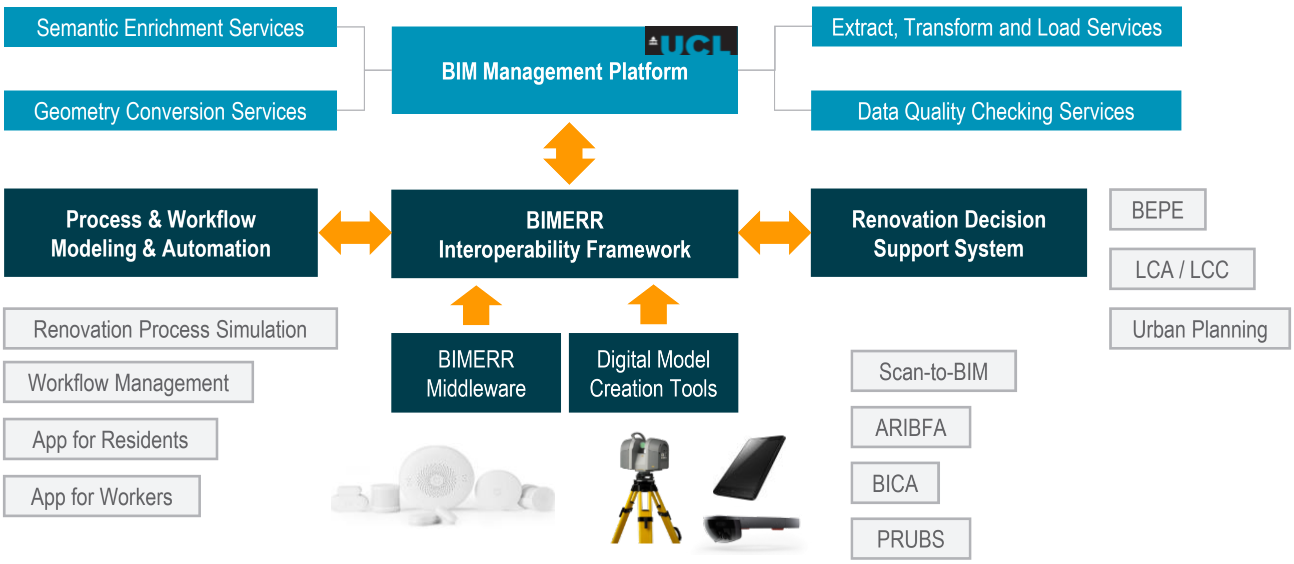

Figure 1. BIMERR High-level architecture.

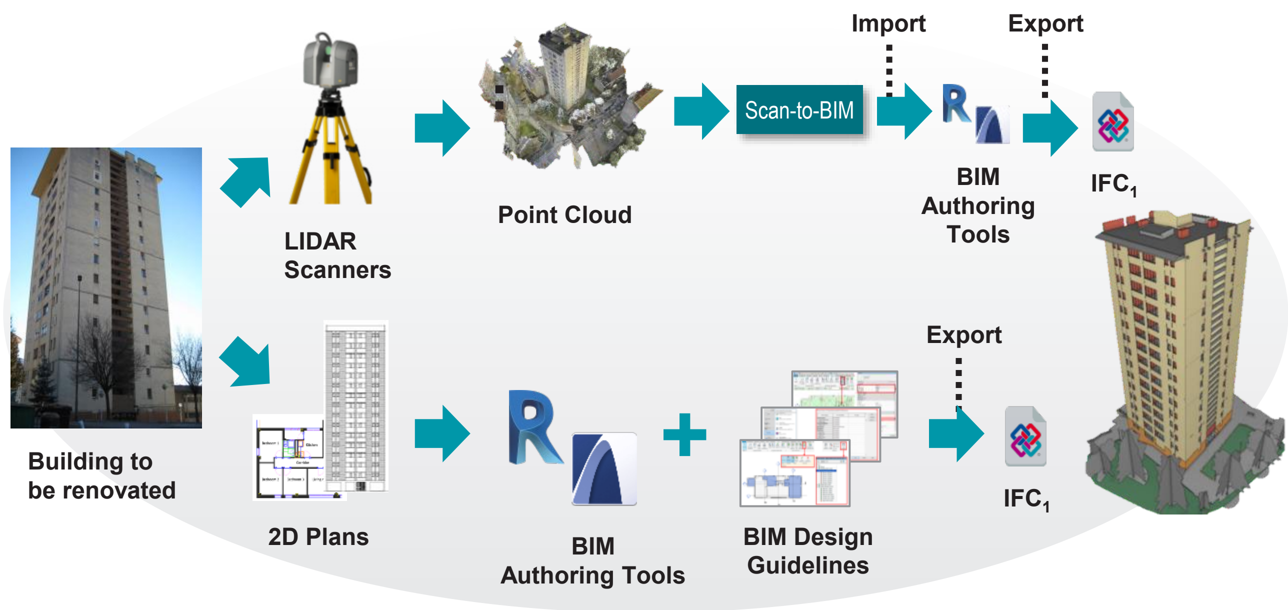

Figure 2. BIM Modelling process.

modellers can build good quality models. We found that importing and exporting IFC models with commercial editors was imperfect and created BIMERR-specific versions of IFC exporters for our requirements.

Whatever approach we adopt to create the model, the resulting model may still have errors or be incomplete in terms of having all the required information. A rigorous model checking procedure should ensure all needed information is present – this is an example of completeness checking. Shown in **Figure 3** is an example of such a check. Given a set of checking rules (in the form of specific Model View Definitions defined by buildingSMART), the platform ensures the model has all the required information. Once these completeness tests have passed, further geometric tests can take place, like clash detection using the platform's cloud-based tools. **Figure 3** shows an example of the model missing thermal properties or a containment relationship for a thermostat.

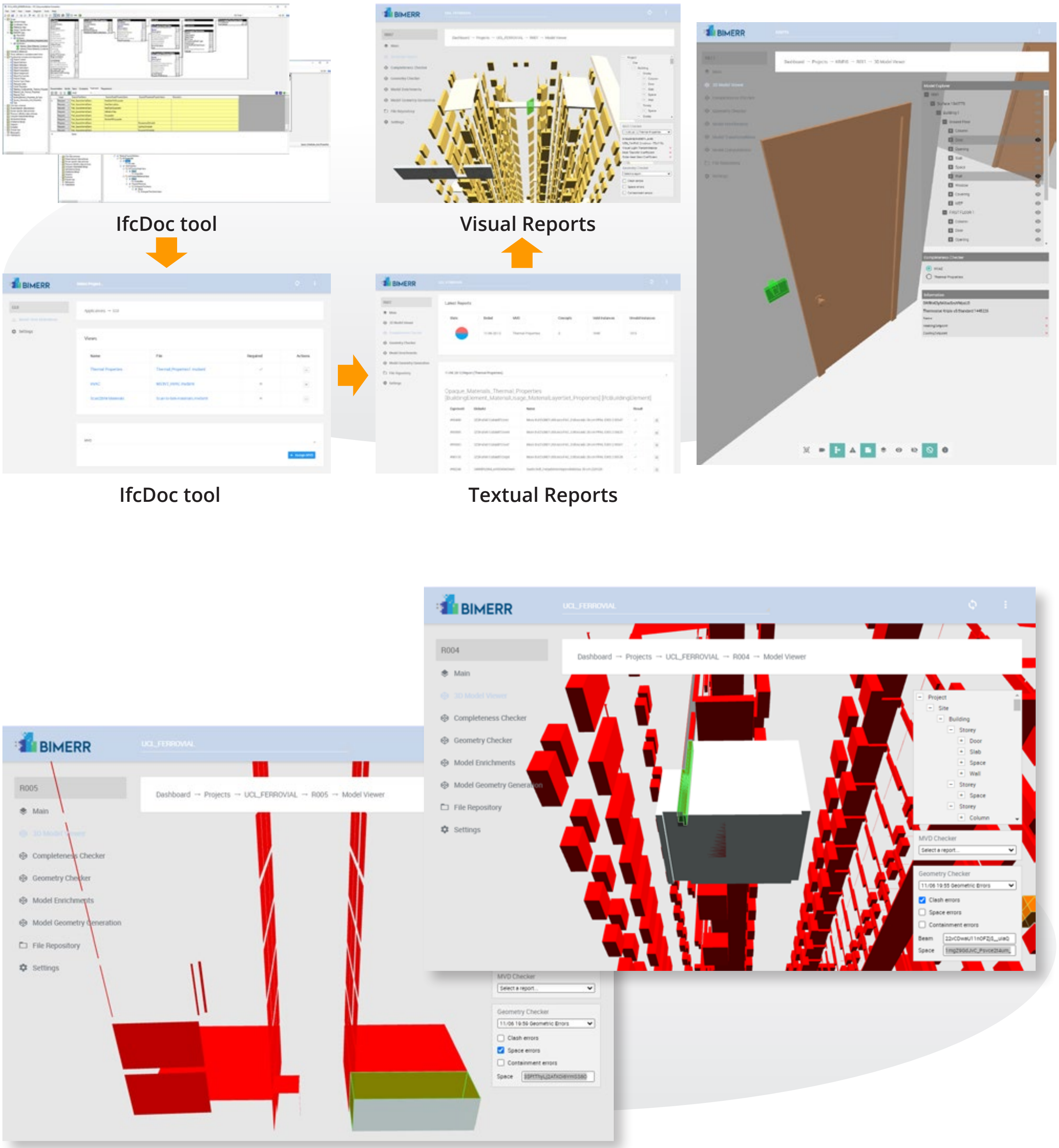

Figure 3. Model completeness checking (top) and Geometric model checking and clash detection (bottom).

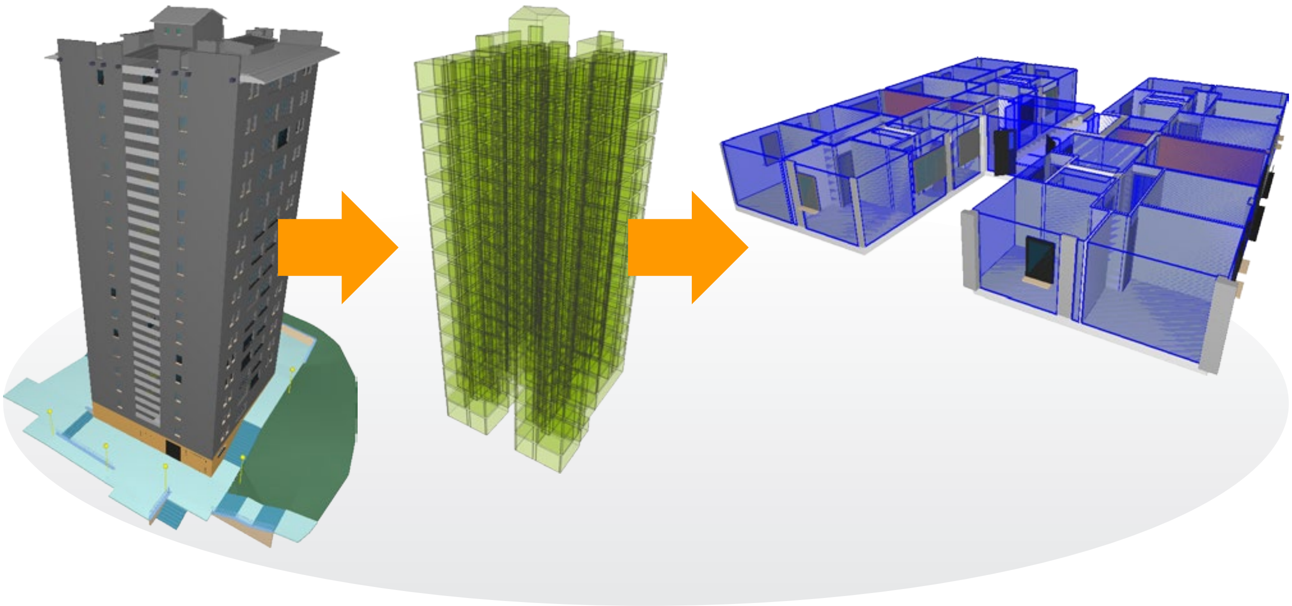

Figure 4. Semantic enrichment.

The data might be further post-processed to be useful for specific applications. Shown in **Figure 4** is the case where algorithms automatically generate spaces and extract thermal transfer surfaces required for energy modelling (2nd-level space boundaries).

This automated procedure can extract this information and enrich the model. The space boundary information can then be easily serialised to create inputs for energy modelling tools (using the E+ data dictionary in our case). The same applies to other details like thermal properties, construction, glazing, schedules, etc. Only a small additional manual effort is required to generate energy simulation models. In a past project, we explored the approach to creating parametric energy models that could be used in an optimisation context to evaluate possible retrofitting alternatives [**3**].

The approach presented allows for a significantly reduced modelling time by up to 50% (in the BIMERR demonstration sites). Perhaps more importantly, the process leads to high-quality data that can be useful for various purposes in the planning and construction phases. ■

Key Messages

For renovation planers, the work highlights potential new tools for planning and implementing energy efficiency renovations.

For policymakers, this research shows digital engineering tools that can improve renovations' quality and encourage investment in energy efficiency changes. Expected impacts include accelerating the renovation rate, helping meet climate targets, and enhancing energy security.

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References

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[3] OptEEmAL (Optimised energy-efficient platform for refurbishment at district level) Available online: https://www.opteemal-project.eu/