IMPRESS BIM Methodology & Software Tools (iBIMm) for Façade Retrofitting Using Pre–fabricated Concrete Panels

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IMPRESS is a H2020 funded project that is developing three innovative prefabricated panels to reduce building energy demand while preserving or improving building aesthetics and thermal comfort. In order to accelerate and optimise the retrofit process, IMPRESS has also developed an Iterative Design Methodology, which incorporates all stages of the Design-Construct-Install-Operate process and aims to bring energy efficiency as early as possible in the design process. Additionally three software tools have been developed for this purpose; (i.) an online Decision Support Software (DSS), to inform decision making on which panel type is suitable for the building; (ii.) an interoperable data exchange server (IDES) to allow storage and exchange of all information related to the design, construction, installation and operation of the facade; and (iii.) an online management platform (OMP) for coordination through all construction stages.

The merger of the design methodology, software tools, standards and guidelines is called "IMPRESS BIM methodology (iBIMm)" which enables design teams to make informed decisions based on building information models. IBIMm includes the representation of the three panels as BIM objects; the transformation of the 3D-scanner data from point cloud files to IFC geometry; the assessment of existing buildings; building energy simulation; execution plan; 3D printing; quality assurance through regular audits; and ongoing operations and maintenance. The validation of the methodology is being carried out in two demo sites located in UK and in Romania.

Keywords – BIM, Façade, Retrofitting, Methodology, Iterative Design, Energy Efficiency, IES VE

I INTRODUCTION

IMPRESS is a H2020 collaborative project that is developing three different prefabricated panels for the over and re cladding of building facdes: (i) a polyurethane based insulated panel (ii) a thin, lightweight pre-cast concrete sandwich panel and (iii) a lightweight pre-cast concrete sandwich panel incorporating Phase Change Materials (PCM) to adapt the thermos-physical properties of the micro particle based coating[1].

To create the panels, an innovative manufacturing process is being created that includes Reconfigurable Moulding (RM) techniques, 3D laser scanning and 3D printed technology. In addition, 3D printed microstructured formworks are being developed as a permanent external layer for the polyurethane panel to match the existing building aesthetics and provide solar radiation efficiency.

The overall manufacturing process will (i) allow for mass production of panels, which take into account complex architectural and aesthetic issues, (ii) allow for faster production while lowering prefabrication costs and (iii) develop new controlled and cost effective solutions.

IMPRESS has also developed a new Iterative Design Methodology, which incorporates all stages of the Design-Construct-Install-Operate process and brings energy efficiency in as early as possible in the design process. This is being integrated with a BIM cloud

[1] For more information: http://www.project-impress.eu/

based database focusing on the interoperability between software tools required for the prefabricated process. The result will be demonstrated on two existing buildings where final as-built product performance will be validated against the initial design.

This paper describes the origins and main characteristics of the iterative design methodology, followed by the three software tools developed in this project, which are (i) Decision support software, (ii) online management platform and (iii) an interoperable data exchange server. Finally, the IMPRESS BIM methodology (iBIMm) is explained, which ties the Iterative Design Methodology with the use of the software tools in order to achieve a successful façade retrofitting project using the IMPRESS panels.

II ITERATIVE DESIGN METHODOLOGY

For the development of the iterative design methodology, the different design methodologies available in the industry were examined and the most relevant and proven ones were considered for greater critique.

These were Integrated Project Delivery (IPD), Integrated Design Process (IDP) and Integrated Energy Efficient Methodology. Briefly, the main characteristics of these area described in table 1, as well as their main weaknesses in table 2.

Table 1: Main characteristics of the design methodologies considered.

Integrated Project Delivery [1][5]	Integrated Design Process (IDP) [2][3]	Energy Efficiency Design (EED) [4]
Involvement of key groups; Shared risk and reward (with liability waivers among key participants); Iterative design with collaborative decision making and control; Jointly developed goals.	Sustainability and Energy Impact; Not lowest installation cost but lowest LCC; Whole system performances considered.	Address energy management during design phase; Minimise energy use; Reduce oversi zing and costs of heating and cooling systems; Energy performance of operational phase.

Table 2: Main drawbacks for the design methodologies considered.

IPD	IDP	EED
Separation of contracts is not clear; Different economic interests at stake; Increased cost of coordination; Does not consider energy performances and LCC goals.	Client full driven; Design costs augmented; Demonstrate value to client is a challenge.	Designed for Industry; Architectural aspects not included; This methodology applies mainly to the design phase.

The strengths of each methodology highlighted in table 1, and the weaknesses in table 2, were reviewed to create a new methodology that takes in to account:

• In-depth stakeholder analysis understanding the interests, drivers and motives of those involved in the prefabricated renovation process.

• Value chain analysis to identify primary and secondary tasks.

• Adequate communication mechanisms and energy management skills for the stakeholders in the process.

• Energy design considerations early in the design process and carries these through to the operation of the building.

• New penalty based business models to ensure that all stakeholders in the design-construct-install-operate process are responsible for the final product performance.

• An auditing strategy to ensure that performance brief is being met.

The main requirements of the new iterative design methodology (IDM) were also:

• Iterative and incremental, meaning that each iteration will result in an increment on the design process.

• Risk-focused, requiring that the project team address major risks before moving to the following stage.

• Model based decision-making, meaning that BIM models containing all the available information from stakeholders is used for making any relevant decision.

• Incorporation of all stages of the Design-Construct-Install-Operate process, allowing decision to be made considering the whole life-cycle analysis of the retrofitting.

• Tested, validated for IMPRESS panels, and replicable for future façade renovation projects.

To address all these requirements, a 5-stage methodology was developed: Initiation and viability, detailed design, manufacturing, installation, and operations and maintenance.

Fig. 1: High-level steps of the IDM.

These steps are intended to allocate as many resources as possible in the early stage of the renovation process. The use of building energy models throughout the design process are expected to provide informed reducing performance inefficiencies. In a similar manner, the use of improvised manufacturing techniques shall reduce material waste and improve the quality of the IMPRESS panels. Figure 2 explains how the starting and ending point of high-level tasks, which are required to any façade retrofitting process.

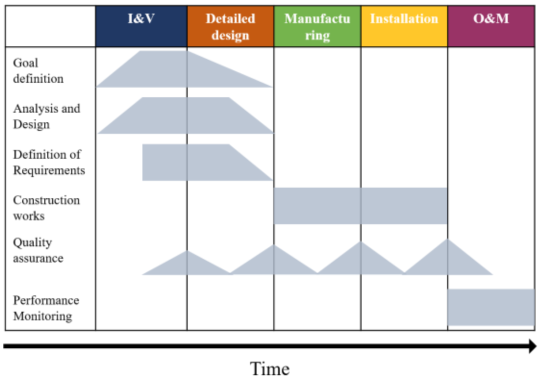


Fig. 2: Resource allocation for high level tasks in the five stages of the iterative design methodology.

It can be noticed, this methodology is intended to focus recourses and effort in the initiation and viability as well as in the detailed design stage. Manufacturing and installation process require strict quality assurance tasks (penalty base business model) and finally Operation and maintenance require a performance monitoring to provide feedback to the models developed during the first two stages.

The two case studies developed for IMPRESS and any new renovation project will feedback early stages in the methodology, reducing resource allocation and hence increasing overall efficiency.

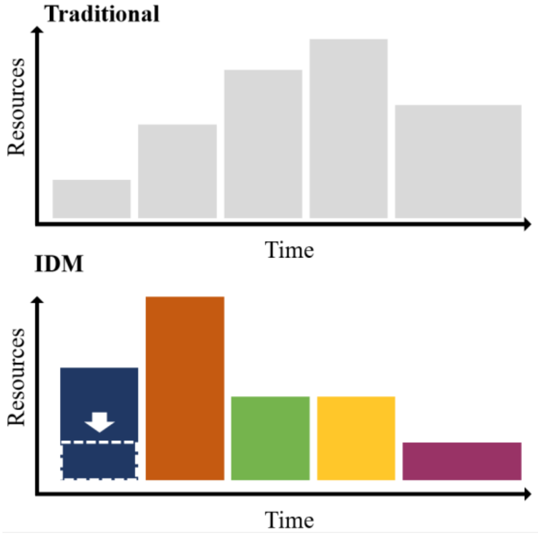


Fig. 3: Summary of the resource allocation for high-level tasks in the five stages (colour coded) of the iterative design methodology comparing to traditional design-construct-operate approaches. Resources for the Initiation and Viability stage to drop over time as knowledge and experience from case studies is incorporated.

The defined the steps are indicated in table 3. Notice that colour code is including indicating the five high level stages. Steps that include (*) indicate the work is carried in the panel manufacturer's facilities.

Table 3: Steps of the Iterative Design Methodology.

Step ID	Name
I.1	Identification of Need and Awareness of Possible Solutions
I.2	Use IMPRESS website and Decision Support Software
I.3	Contacted by IMPRESS Commercial Service
I.4	Building Survey/ Assessment
I.5	Agree Project Performance Brief (iterative with step I.2)
I.6	Evaluate and Cost Project Resource Requirements
I.7	Establish an in-house Project Team
I.8	Provide Costed Options based on optimised Integrated Design Process

I.9	Agree and sign contract (Milestone)
II.1	Implement QHSEE Management Policy and Procedures
II.2	Undertake 3rd Party Consultation- Site Development Issues
II.3	3D Building Survey
II.4	Generate BIM Model
II.5	Develop panel design and structural support system
II.6	Energy Performance Simulation (iterative with step I.4)
II.7	Complete and Approve BIM generated design documents
III.1	Formwork*
III.2	Incorporate monitoring sensors*
III.3	Panel casting*
III.4	Demoulding/Curing*
III.5	Installation*
III.6	Transport
IV.1	Installation
IV.2	Install and commission Panel sensors
V.1	Ongoing BMS Sensor Monitoring and Data Collection
V.2	Decommissioning and End of Life Plan

III DECISION SUPPORT SOFTWARE (DSS)

The web tool helps users to make informed decisions on whether IMPRESS pre-fabricated panels are a suitable refurbishment option for their building and which of the three different panel types suits best. The software carries out this analysis by mapping users' answers from a questionnaire to suitable retrofit options.

Additionally, it assesses what effect the refurbishment will have. Aspects of interest are financial, energy and CO2 emission savings. The decision is based on building energy simulations of the building pre- and after refurbishment. The building energy simulation software embedded in the tool is the IES Virtual Environment (IES-VE).

IMPRESS DSS is a freely accessible tool to help people assess their options for retrofit cladding for their own building. However, it is not designed to replace the work of an engineer or architect, but merely to engage potential clients, help them better understand the potential benefits of a façade retrofit for their particular building and create a building energy model as early as possible. Thus, potential energy / CO2 emission / etc.; savings calculated by the tool shall only be seen as a guideline rather than as a promise to the user to save exactly this amount.

The main benefits of these tools are:

• Minimum data collection

• Can be used by non-experts,

• Generation of results in a few minutes,

• Creates an energy model that is used as starting point for the design stage in case clients decide to go for the IMPRESS solution.

This tool is intended to work with the IMPRESS pre-fabricated panels as it has preloaded thermal performance information from panel manufacturers. Hence IMPRESS solution will range between the three types of panels or "non suitable" for the cases where construction codes restrictions or existing high-performance facades would suggest that IMPRESS panels are not adequate. Other solutions such as windows and/or HVAC retrofitting are not addressed in the DSS.

Fig. 4: Welcome page of the Decision support software (DSS).

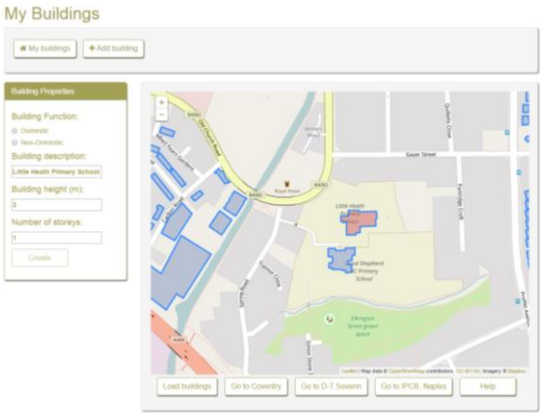


Fig. 5: In the DSS, user selects the building on the Open Street Map and then fills in a simple questionnaire.

The result page in the DSS is similar to figure 6. Notice how potential savings are displayed terms of percentage of reduction as compared to a baseline model. This approach allows simple calculations of the return of investment (ROI) for feasibility analysis.

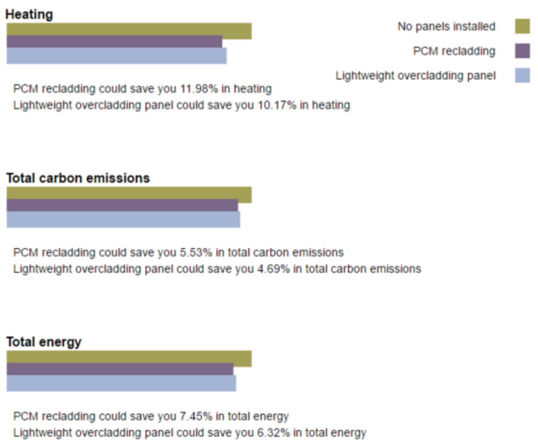


Fig. 6: Percentage in heating energy, carbon emissions, and total energy savings for two IMPRESS panels as compared to a baseline model.

Additionally, an estimated building energy breakdown is available for users to better understand opportunities for energy savings, as shown in figure 7.

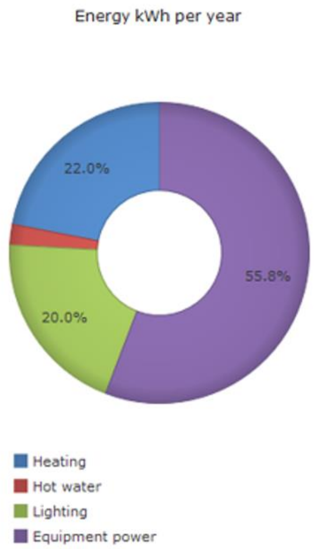


Fig. 7: Building energy breakdown estimated in the building energy simulation based on the questionnaire information provided by the user.

The validation of these results from the two case-sties and future renovations will increase overall accuracy of the DSS minimising risks for stakeholders. In addition, the early stage energy model can be used as starting point for the following stages in the process. This is described in figure 11.

IV Online Management Platform (OMP)

The Online Management Platform (OMP) is a web based project management and collaboration tool designed to ensure correct use and easy uptake of the iterative design methodology. It includes all the necessary tools to allow for efficient collaboration between the project team of a facade retrofit project, and the friendly and customisable user interface encourages the passive stakeholders to engage and participate in the iterative BIM Level 2 friendly design process.

The main features include an interactive Gantt chart, which lists all the tasks in the project with their status and deadlines, fully customisable and manageable by the user according to their needs and based on their level of access. The platform also includes a file upload mechanism which was designed to follow BIM level 2 collaboration standards, to enable easy file sharing, reduce the unnecessary file duplications and allow for auditors to verify and authorise files shared among the stakeholders in the retrofit project.

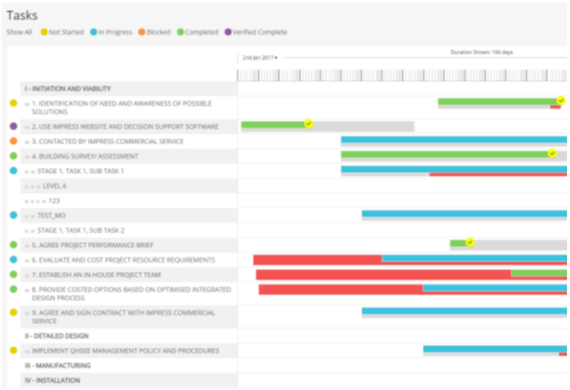
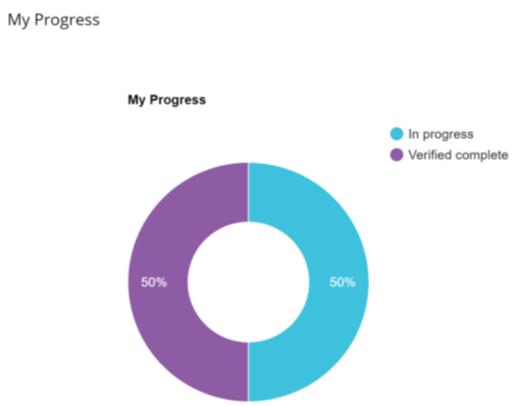


Fig. 8: Gantt chart view in the Online manage platform.

The users of the OMP will be all the stakeholders involved in a façade retrofit of a building using prefabricated concrete panels. Depending on the level of participation of each stakeholder, various levels of access have been created in the platform, including administrators and standard users.

Project managers are able to organise and track the progress of tasks defined as part of the methodology while ensuring a secure, easy and efficient collaboration and file sharing. Additionally, this tool is auditing-friendly designed to allow regular audits for quality assurance purposes and is available on desktop, tablet, and mobile.

In the context of BIM Level 2 standards, there is a task view to visualise work in progress (WIP) tasks, also metadata features such as suitability and versioning are required for any file upload upon upload. These files are in turn stored into a shared section for collaboration.



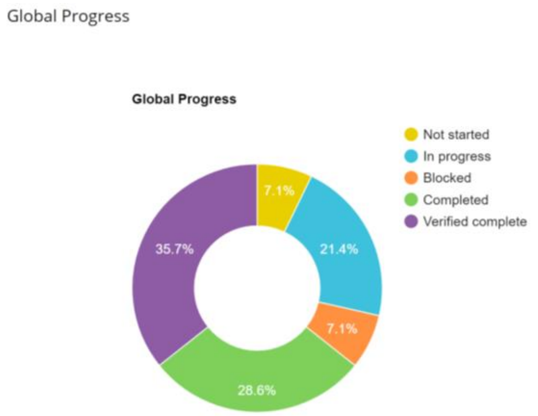


Fig. 9: Tasks view in the Online manage platform.

V Interoperable Data Exchange Server (IDES)

The Interoperable Data Exchange Server (IDES) allows all software tools and data within the prefabricated renovation process to communicate and exchange data with each other. This software is currently under development and will ensure the interoperability of various domain models, e.g.: 3D CAD Modelling Software for Architectural Design3D, Laser Scanning Software for creation of point cloud data, Energy Design Software, Prefabricated Panel Software for manufacturing and ongoing monitoring. This will be achieved through a web-based platform able to store and merge industry the foundation classes (IFC) data models from each discipline or domain alongside with other formats such as Comma Separated Values (CSV) for the case of Building Management Systems (BMS) and other metered data.

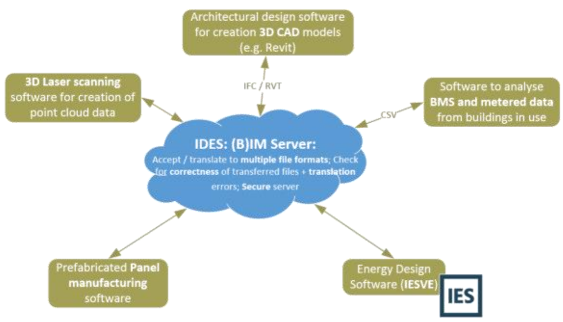


Fig. 10: Integration of data models from different disciplines in the IDES.

A federated model –which is a model consisting on connected but distinct models [7] – is created to maximise collaboration and information exchange between stakeholders thanks to its model merging capabilities.

VI Software and Methodology Integration

A BIM methodology based on the Iterative Design Methodology that can be integrated seamlessly with the software tools is necessary to guarantee an optimal workflow and guarantee efficiency in the process. Figure 11 shows how the iterative design methodology is linked with the three above described software tools in a high level.

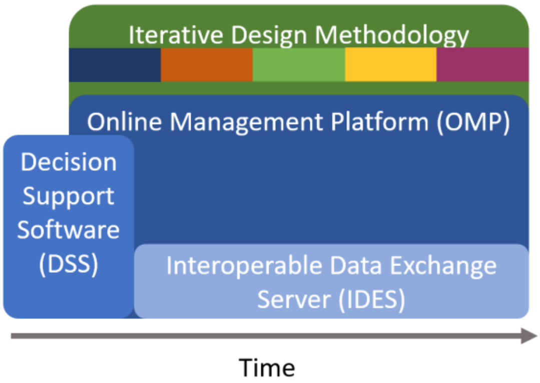


Fig. 11: Integration of the Iterative design methodology (in green) with the IMPRESS software (in blue).

A core part of the iterative methodology is the model collaboration for decision-making; hence, the IDES is a key software that converts an early stage energy model created with the DSS into a more detail BIM model as the project moves on. Also, it enables an optimal workflow specially when dealing with the iteration of the design between stakeholders.

The role of the OMP lies throughout all the stages of the project, and together with the Interoperable Data Exchange Server (IDES) constitutes the Common Data Environment (CDE), in the context of BIM level 2.

Figure 12 describes the relationship of the 5 stages of the iterative design methodology, IMPRESS software, 3rd party software and the main actors involved in the renovation process.

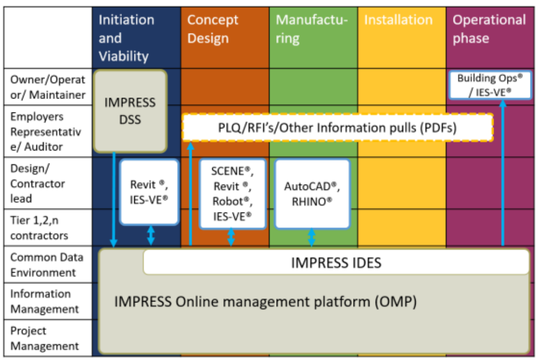


Fig. 12: Detailed relationship between stages in the iterative design methodology, IMPRESS software and 3rd party software.

Regarding versioning, the IDES is developed to support model versioning between project stages. At the end of each stage, models created shall be archived for future reference.

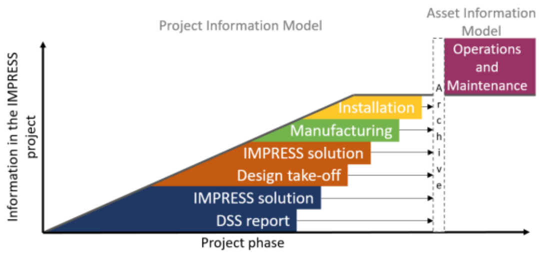


Fig. 13: Model versioning in the IDES. At the end of each project phase the latest version of the models shall be referenced for future references.

The main benefits of the IMPRESS BIM methodology are:

• Avoidance of duplication of information;

• A comprehensive methodology that covers not only the design stage but also operational phase;

• Online management platform containing all the required tasks per stakeholder;

• Maximum collaboration between stakeholders providing them with the most updated information available;

• Enables an iterative design by allowing the quick exploration of multiple design options and the impact on the energy consumption of each of them.

X Conclusions

The iterative design methodology can be summarised as an iterative and incremental, risk-focused, approach for model based decision-making during all stages of the Design-Construct-Install-Operate process, that and has been tested, validated for its use on building facade renovation with IMPRESS panels.

The DSS is an early stage energy simulation tool that help non-expert users to make informed decisions on whether IMPRESS pre-fabricated panels are a suitable refurbishment option for their building, and when this is the case, the DSS creates a report with the potential energy savings by using each of the three IMPRESS panels.

The OMP contains all the tasks from the Iterative design methodology allowing visualising and following up each of the required tasks. Also works as a file management platform.

The IDES is a web-based tool that enables model based collaboration between different disciplines through federated models iBIMm consist on the seamless integration of the Iterative Design Methodology and three pieces of IMPRESS software that enable energy efficiency considerations in the early stage of the design process.

During later stages of the project, further validation work on the two case-studies will be carried out to ensure that the iBIMm is taking full advantage of the developed web tools.

XI ACKNOWLEDGMENTS

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