Web-Based Communication Platform for Decision Making in Early Design Phases

Z. Meng[a], A. Zahedi[b], and F. Petzold[b]

[a]Chair of Construction Management & Economics, University of Wuppertal, Germany
[b]Department of Architecture, Technical University of Munich, Germany
E-mail: meng@uni-wuppertal.de, ata.zahedi@tum.de, petzold@tum.de

Abstract –

During the early phases of building design, the architects create many variants and make important decisions about different design aspects and details mostly based on their own experience and know-how. In order to reduce the risks brought by arbitrary decisions, a lot of effort was put into developing simulation tools. However, most of these simulation tools require more elaborate details as what is available during these early phases, or they will provide some cumbersome results via oversimplification. Therefore, it is equally important to develop a communication tool enabling the earlier integration of suggestions given by diverse domain experts. Hence, a research based on the concept of adaptive detailing has been made by Zahedi and Petzold since 2018, according to which those suggestions and feedback provided by multiple domain-experts could be documented using a minimized machine-readable communication protocol based on BIM [1]. Consequently, an online platform for supporting the collaborative work through adaptive detailing at early stage of design is developed in this paper. This paper focuses on the Optimization of workflow and effectiveness of user interface in this platform. As evaluation of this platform, a user-study was carried out among students and practitioners in AEC industry. The result of user-study not only practically verifies the usefulness of this tool, but also implies the difficulty in transforming the daily communication mode into digital platform.

Keywords –

Building Information Modeling; Early Design Phases; Adaptive Detailing Strategies; Computer Supported Collaborative Work

1 Introduction

The integration of Building Information Modeling (BIM) applications at early stage of design have great impact on the final design and overall cost, while the additional costs resulting from design changes in early phases are also significantly lower [1]. Furthermore, the main idea of BIM is about the exchange of information including 3D-models with semantics among the participated domains [2]. For the reasons above, early collaborative work is of great importance to improve efficiency of design in a project.

However, according to our online survey 31.5% of the students or practitioners from the Architecture, Engineering and Construction (AEC) industry have tried BIM software as communication tool before at early stage of design, whereas 78.9% of them use BIM products for 3D modeling in design phase. Those statistics prove that more attention should be put on developing BIM tools for communication in design phase, so that diverse domain-experts could better help the architects by providing suggestions from their point of view.

This work aims to develop an online communication platform with optimized workflow and user interface, based on literature review on computer supported communication and collaboration, as well as on other BIM based communication tools on the market. The effectiveness of this platform would be validated during a user-study at the end of this paper.

2 State of the Art

2.1 Adaptive Detailing Strategies, Multi-LOD, and Building Development Level

Although many model-based planning tools are currently available, they require extensive input data and detailed model construction even in the early design phase. However, a model that is too precise and reliable can lead to incorrect assumptions and evaluations, such as in energy calculations or structural analyses, which affect planning decisions in all planning phases [2][3]. In order to close this gap, the research unit FOR2363 from German Research Foundation (DFG) is developing methods for the evaluation of architectural design

variants in the early stages of their development by means of adaptive detailing strategies that allow the detailing and evaluation of alternative, partially incomplete and vague building models [4]. This research project is also called Early BIM. To allow the explicit expression of potential information vagueness in the design phase, the research group develop a multi-LOD meta-model. Under the case of that, it is possible to define the uncertainty of information as well as building components at different LODs in a design variant [3]. A new concept called Building Development Level (BDL) is therefore introduced to describe the maturity of building models at difference design stages [3]. The BDL concept is also used in this project as milestone for new requirement of decision making.

2.2 Computer Supported Communication and Collaboration

To further promote communication and cooperation in the BIM field, the introduction of a research area called Computer Supported Cooperative Work (CSCW) is unavoidable. CSCW investigates on an interdisciplinary basis how individuals cooperate in working groups and how they can be supported by information and communication technology [5]. In this section mainly the socially acquired phenomena of CSCW research are described, whereas the technological aspects are explained afterwards in section 2.3.

Communication between the cooperating partners is the prerequisite for cooperation. The goal of cooperation is to coordinate the work processes and technical interfaces of the project participants as optimally as possible and to ensure a consistently efficient use of information [6].

2.3 File Formats for BIM Based Communication

The best-known collaboration format is the BIM Collaboration Format (BCF) from buildingSMART, which supports workflow communication in BIM processes. Project participants can use it to create various topics, such as problems, proposals and change requests. The BCF also allows the structured description of model conflicts or defects. Among other things, the camera position and the viewing direction are transmitted for the representation in the 3D model.

Since version 2.0, the BCF format also offers schematized files and machine-readable topics. However, this format is mainly used as comment based and human readable [4]. Therefore, based on the concept of adaptive detailing, and for better documenting suggestions and feedback provided by multiple domain-experts, a minimized machine-readable communication protocol based on BIM was developed by Zahedi and Pezold [6].

Using this protocol, a Feedback package contains information about:

- missing details in a design variant that are essential for a certain simulation to be performed
- suggested options to fulfill those missing details.

Further details about this minimized BIM-based communication protocol is discussed via demonstrative examples by Zahedi and Petzold [4][7]. Using this computer-interpretable protocol in communication tools can largely reduce the misunderstanding incidences in the whole progress.

2.4 BIM Based Communication Tools

With the development of software in AEC industry, many solutions which were mostly used for IT companies are now also integrated in BIM applications. For example, the ticket system, mainly used for tracing every request from the start until its completion, was firstly used in IT companies where a huge number of requests are produced in daily basis, is now widely embedded in BIM communication tools. Those tickets are normally shown in a dashboard and named “issues” or “tasks” in BIM based communication tools. Other frequently implemented functions are, for instance, presentation of the up-to-date overall information about the project, message notification, 3D visualization, marking and commenting on models, merging the partial models, preview of interim document, etc. The most popular BIM based applications such as Autodesk BIM 360, BIM Plus from Allplan, thinkproject, etc. have included all of these functions. However, the visualization mode of different types of data is seldom discussed. To fill this gap, various types of viewing mode or graphics will be provided in this project and tested via user evaluation.

3 Concept and Methodology

Practitioners in AEC industry are long used to conventional communication media such as face-to-face meetings, telephone, fax and email. However, for better decision making and more efficient information exchange in early design phases, it is reasonable to integrate BIM common data environment into the communication tool. In this way, the function for file exchange, preview of design variant and intuitive comparison of simulation results can be feasibly embedded (Figure 1).

As Lubich in Figure 2 suggested, the proper way to develop a CSCW tool starts from representing the working environment. In this case it means to explain how communication between project participants actually works, or what the conventional working environment in the construction industry is. Turk

explains that the most important activity in the construction industry is not "processing", such as problem solving or decision making, but maintaining a network of conversations in which requests and commitments lead to a successful completion of the work [8].

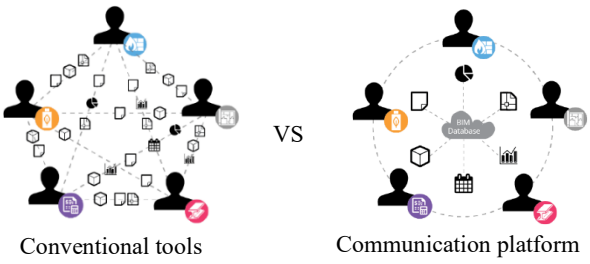

Figure 1. Compared to conventional communication, different communication methods are integrated into the new web-based platform.

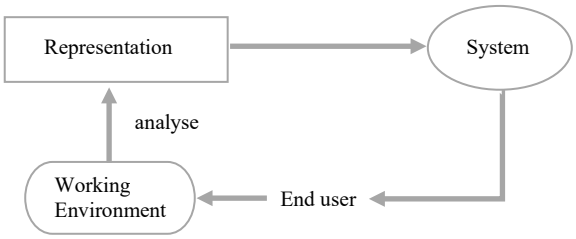

Figure 2. Development cycle of computer-aided collaboration software [9] (first orally presented by J.E.Dobson in 1991)

As we can observe in real working environment, it might possibly happen that an architect asks a civil engineer to check about the load-bearing structure, and the engineer accepts the request. Several days later the architect asks the engineer about whether the simulation result is generated or not. And finally, the engineer informs the architect that the task is finished. Of course, in most cases this process doesn't run smoothly, and there are normally special occasions happening during the process. Winograd and Flores have named such an interaction "conversations for action – those in which an interplay of requests and commissives are directed towards explicit cooperative action" and have therefore mapped the possible answers at each point in a conversation in an example model (see Figure 3) [10][11].

In this model, for example, one party (A) asks a question to another party (B). The request is interpreted by each party to meet certain conditions. After the initial statement (the request), B can accept (thus commit to meet the conditions), reject (to end the conversation), or make a counteroffer with alternative conditions. Each further confirmation has its own possible continuation (e.g. A can either accept, reject, or offer again the counteroffer from B). This diagram is not a model of the mental state of a speaker or listener but shows the conversation as a "dance" in which the actions create the structure or termination of the conversation.

To further use this model in the implementation part, it is translated into a graphical specification language, the Business Process Model and Notation (also known as BPMN) (see Figure 4).

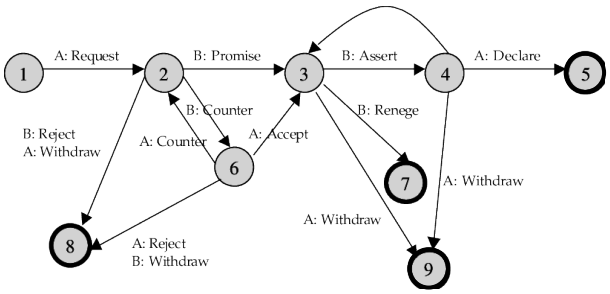

Figure 3. The basic conversation for action process model [10]

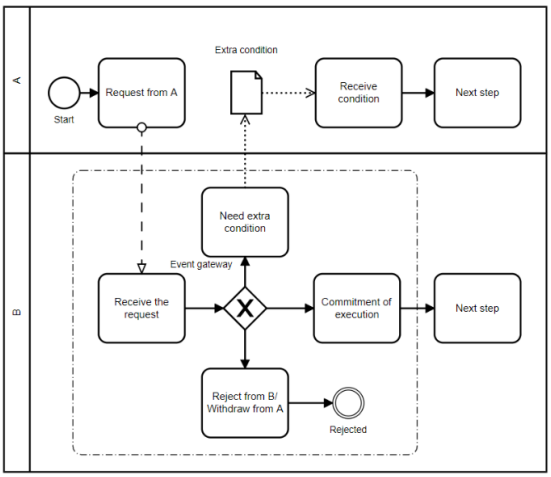

Figure 4. Simplified BPMN of the "conversation for action" model adapted to Maaß, 1991 [11]

4 Implementation

The implementation of optimized communication tool is carried out in two steps: 1. Definition of proper workflow of communication (corresponding to "Representation" in Figure 2); 2. Developing the tool (same as "System" in Figure 2).

4.1 Definition of optimized communication workflow in the platform

In the beginning of this step, a few concepts which are very often used in the workflow must be clarified:

- VARIANTS are the different versions of the design, which architects offer as a proposed solution.
- OPTIONS refer to the suggestions for the missing parts in variant which are provided by domain experts. The architects then may choose one of these options to fulfill the requirements for simulations.
- REQUEST contains the information of an action that the architects ask domain experts to execute, for instance, the request of simulation or request of options for missing parts. It is a kind of "Request for Information" (RFI), which is often used in business processes for collection of information and making decisions.
- FEEDBACK is the message that domain experts give to the architects including their reaction on the request, such as rejection, agreement, as well as further information. There could be three types of feedbacks: 1. Interim report on missing values which are necessary for the analysis or simulation; 2. Interim report with options; 3. Final report on simulation results and evaluations of various variants. Since a file format "feedback package" especially for the case of communication is invented [4][7][13], it will be used later for accurate expression of the feedback.

The workflow of this whole communication system is divided into three scenarios (Figure 5):

1. Request for analysis
At a certain point, the architect needs simulation results and evaluations from other specialist planners. Therefore, he sends the planner a request for analysis by ticket. Using the ticket system, the whole process can be monitored and managed. General Information such as actor, deadline of the request and the processing status of each request/ticket can be displayed. According to the conversation to act model [11][12], there can be three possible types of reaction to any request for an action [4][7][13]: accept, reject or counteroffer with alternative conditions. If some geometric details or semantic information, which are necessary for further analysis, is missing, the specialist planner will give a feedback to the architects.

2. Request for options and update the variant
In this case, after step 1, the architect receives a feedback with a message containing the missing values. Then he precedes to ask for options to continue the process. Although in the normal working environment, mostly an architect makes decisions based on his knowhow, but using adaptive detailing he could ask for experts' opinion via request for options.

After the request, options for missing components, their consequences on analysis results, as well as a comparison between options will be packed up and sent back to the architect as feedback. The Architect would then evaluate the properties of each option, make a choice, and complete the variant model. The variant is therefore updated during the process.

3. Execution of simulation and optimize the variant
The execution of the simulation can only be

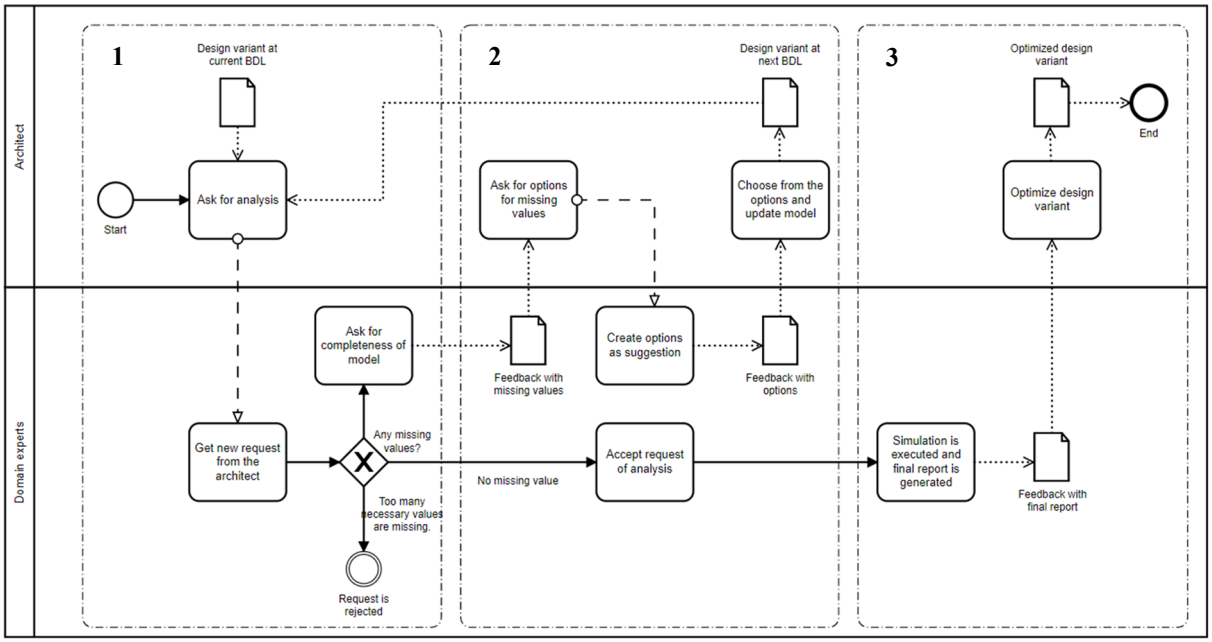

Figure 5. BPMN of the conversation for action Process between architects and specialist planners

achieved if the coordination model has already been checked by all the domain experts and has no more missing values. After the simulation, each domain expert submits a report with simulation result of the variant and their suggestions for optimization. The architect then collects all reports and accordingly improves the variant.

The objective of this whole workflow is to let domain experts give suggestions from their point of view as early as possible. It consequently prevents the case of endless revising on design model and reduces the potential problems which can become big issues in later phases.

4.2 Building the web-based communication tool with ideal user interface

4.2.1 Design of user interface

After the communication process is created, the functions in optimized workflow are first summarized in Table 1, so that the required items and their file format as well as possible visualization forms are categorized.

To visualize the core function of this communication system, which includes sending request and receiving feedback, a dialogue panel is created. On the dialogue panel, notification of new message, basic information in request or feedback, and project profile will be presented. Also, a block for free discussion between group members is available on the dialogue panel. In order to spare extra place for presenting content in details, the dialogue panel is designed as foldable (see Figure 6).

According to Gadelhak, Lang and Petzold [14], it is recommended to use a dashboard to display the attached information of the conversation. On one hand, several options can be displayed on different panels of a dashboard. On the other hand, the dashboard gives an overview of all relevant performance aspects of the building and can provide detailed information at the same time if required. The dashboard is therefore in this case particularly applicable for presenting and comparing various options or variants contained in feedback (see Figure 6).

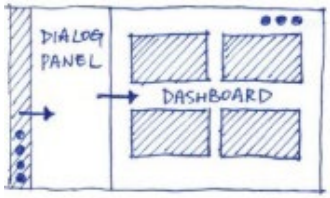

Figure 6. Layout and navigation of platform

4.2.2 Frontend development

In this project the frontend of the web-based application is implemented. There are two types of files to be visualized: the IFC files such as the coordination model and partial model, and the CSV/ JSON files that

Table 1. Information to be visualized, corresponding file format and possible visualization form in platform

Role	Function lists according to workflow in Figure 5	Required items	Data/ File format	Visualization form
General	Show variant at current BDL / at next BDL	Participating projects of the user	JPG / TXT	List / Images
		Information about the user	JPG / TXT	Text / Images
		Participants in a project	JPG / TXT	List / Images
		Process log	CSV	Graphic
		Project status	CSV	Graphic
		Fixed meeting	JSON	Dialogue
Architect	Request for analysis by ticket	Message of the request	JSON	Dialogue
		Coordination model	IFC	3D / Images
	Request for options	Message of the request	JSON	Dialogue
	Update variant	Coordination model	IFC	3D / Images
Domain experts	Feedback with rejection	Message of the feedback	JSON	Dialogue
	Feedback with missing values	Message of the feedback	JSON	Dialogue
		Partial model	IFC	3D / Images
	Feedback with approval	Message of the feedback	JSON	Dialogue
	Feedback with options	Message of the feedback	JSON	Dialogue
		Performance of the options	CSV	List/ Graphics
		Partial model	IFC	3D / Images
	Optimize variant	Coordination model	IFC	3D / Images
	Feedback with final report	Message of the feedback	JSON	Dialogue
		Partial model	IFC	3D / Images
		Annexes	DOC / PDF / JPG / IFC	List/ Images
		Final report	CSV	List/ Graphics

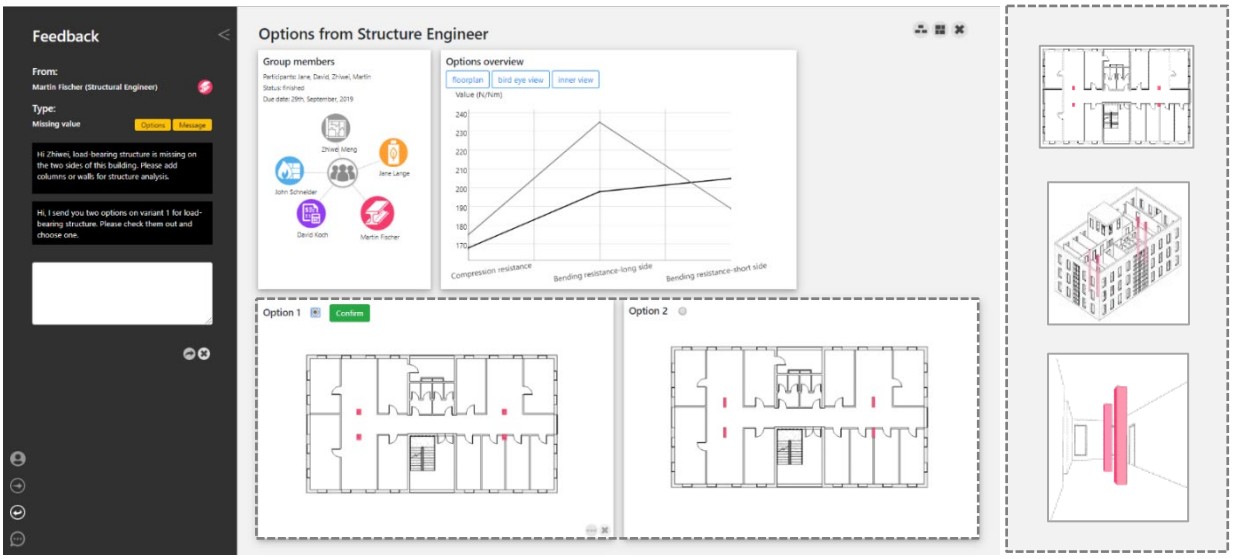

Figure 7. Various visualization mode for options

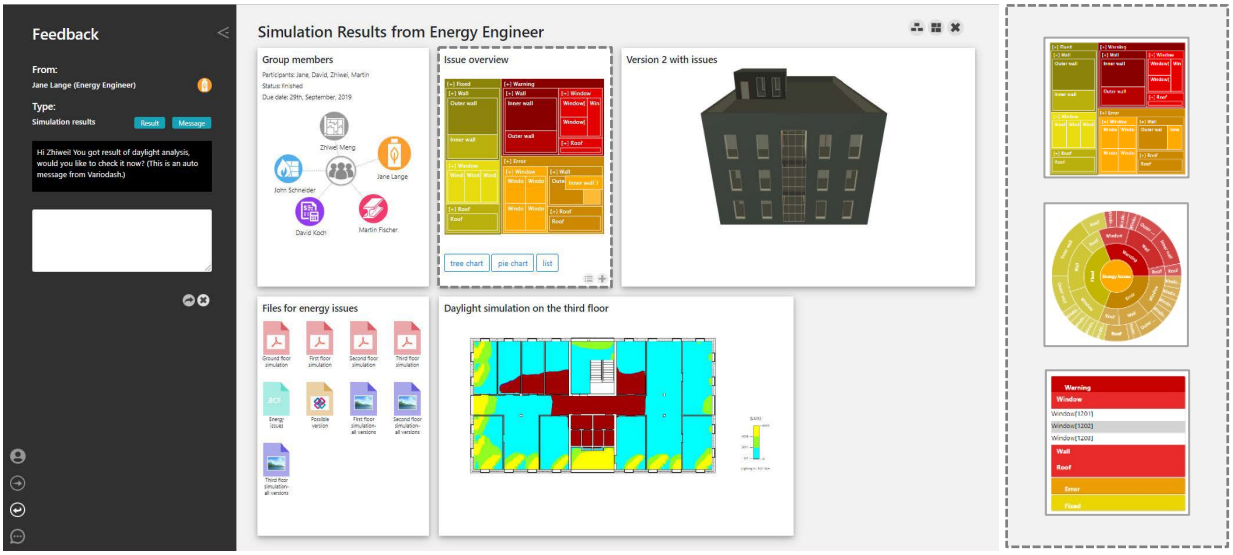

Figure 8. Different graphical representations of simulation results

capture the log and problems in the process or final report. The IFC file should first be transferred to the Obj file by data preprocessing such as ifc OpenShell or xbim toolkit. After that it is visualized by ObjLoader.js (provided by three.js) on the web page. Another important file type is the CSV file, which can record the process log, project status, option performance and final report. To visualize the data in several display modes, the libraries of ZingChart and Dygraphs are used specifically. To validate the specific process of implementation we take a three-storey office building of Ferdinand Tausandpfund GmbH & Co. KG [15] in Regensburg, Germany as an example. After the functions are organized and implemented, a web-based application could be developed.

Because all the information of requests and feedbacks is collected on the side of architect, it is meaningful to show the user interface from this view. As Figure 7 and 8 present, various graphical representations are provided. For comparing the options, user can choose floor plan view, bird eye view or inner perspective view (see Figure 7). And for identification of issues in simulation results, user can define a visualization mode from tree chart, pie chart or list (see Figure 8). As mentioned before in 2.4, one important objective of this project is to provide different visualization forms so as to test which one is more preferable for the user and gives the architect more intuitive criteria in decision making [13].

5 Evaluation

Since the implementation of the web-based communication tool is completed, 19 students or practitioners from the AEC industry were invited to participate a user experience study. After experiencing the whole process, more than 60% of the participants consider the platform to be usable in most cases.

It is worth mentioning that in the answer to the question "Which tool do you think is irreplaceable through this platform?" more than a half of users (almost 58%) still consider the face-to-face meeting as irreplaceable. It is very interesting for us because in hypothesis we considered the face-to-face meeting as the most likely replaced media. Some of the reasons given by respondents are:

- The personal meeting is always the most dynamic one and gives the quickest results.
- It can help solving complex problems.
- It is a quick and direct communication way.
- It is real time communication. Whenever you put up a question, there would be an answer immediately.

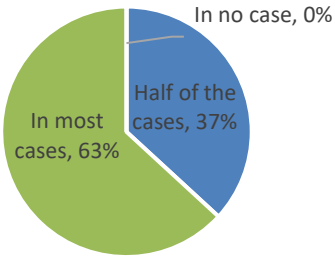

Figure 9. Answer to the question "In how many cases do you think this platform is applicable?"

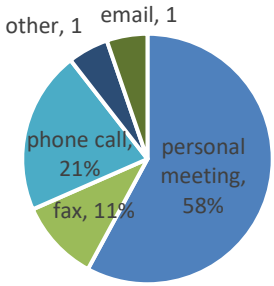

Figure 10. Answer to the question "Which of the following means of communication is irreplaceable by this platform?"

According to the user study, the communication system is helpful especially in illustrating the feedback, and the display of the simulation results. More specifically, most respondents chose bird eye view as best visualization mode for options (50%), and the list as most efficient graphical presentation for issues during simulation (50%) (see Figure 11 & Figure 12). These results for favorite graphical representation can be used later in other corresponding products.

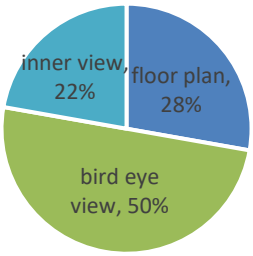

Figure 11. Answer to the question "Which of the visualization mode do you think is most suitable for presenting options?"

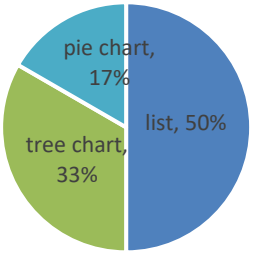

Figure 12. Answer to the question "Which of the graphical presentation do you think is the best for reporting issues in feedback?"

In the end there are also several suggestions for optimizing the communication platform:

- More real time communication in the model would be helpful.
- The authority levels from different users should be distinguished.
- In most of the cases, speedy replies are expected, therefore it would be great if the message notification can be improved and the hint of message priority can be tagged.
- The text should be bigger.

These suggestions are significant indicators for further development of this tool as well as for other similar products.

6 Conclusion

While the market for BIM applications is growing rapidly, there is still no effective working method for architects to propose the variants and discuss with other project participants about design. With the development of adaptive detailing strategies and multi-LOD, it is possible for the domain experts to participate in early design phases and to give suggestions even if there is still missing or vague values in design model. Furthermore, after the literature review on existing BIM based communication tools, the most practical functions, such as the ticket system, are collected and included in this case, whereas the request and feedback functions are embedded as core mechanisms for the communication workflow. Consequently, a BIM based communication platform especially for discussion at early design stages is built based on a specified workflow and in the end validated by a user-study. The result of the user-study shows an overall acceptance of this tool among users, as well as the preferred visualization mode for data in the feedback. These findings could be referred as important hint for further research or for software development in BIM field.

Considering the contribution of this communication platform, it was rewarded in year 2020 as the first prize in the category of Architecture in "Built on IT - Building professions with future" (Auf IT gebaut 2020) federal competition in Germany under the patronage of the Federal Ministry of Economics and Energy [16].

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