Integration of real-time construction planning scenarios with theoretical studies of building services and piping technology - A practical approach

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Abstract

A paradigm shift is taking place in the architecture, engineering and construction (AEC) industry, leading to higher productivity, efficiency, quality, sustainability and value of the infrastructure, while reducing life cycle costs and project duration [1]. This, in turn, has impacted the academic sector as well, giving rise to new disciplines such as smart building engineering [2]. Such a course can only be successful if the theoretical foundations are brought into line with industrial practice. In this background, the presented project was conceived as group work for engineering students of higher semester within the course of piping technology and plant engineering. In this project, the students are given the task of creating a 3D construction model with a Building Information Modelling Level of Detail (BIM-LOD) of 400 [3] i.e. with all manufacturer-specific components of a mechanical room with a given system schematic and architectural model. The aim is to give students a detailed and realistic insight into the real-time planning of construction projects, to gain initial practical experience in the creation of BIM models and implement what they have learned in theory and gain a comprehensive knowledge and understanding of the subject. The project experience aimed to prepare the students for challenges in planning building services that they may encounter in their future professional life in construction projects. A further extension of the information part of a BIM model was also considered, as students are expected to provide maintenance-related attributes such as manufacturer name, type and article number to the components used in the BIM model along with the material lists that are required for construction. The project was implemented as a voluntary commitment for the students in the year 2021 as a pilot phase with the creation of a construction BIM model of a mechanical room using Autodesk Revit 2020 software [4] which turned out to be an excellent training exercise for a real-time construction planning scenario for the students. In the current year, the project is planned to be further developed by integrating even more disciplines such as ventilation foreseeing extensive planning and coordination of a construction project.

Keywords: *Smart Building Engineering, BIM, Construction projects, Real-time scenarios*

1. Introduction and motivation

The evolution of computers and information technology led to a digital revolution in the AEC industry that, in turn, gave rise to the Building Information Modelling (BIM) technique. BIM is a process that generates and manages digital representations of buildings in terms of both physical and functional characteristics. The most common misconception among the stakeholders is limiting BIM to 3D modelling software. BIM is not only a software but a holistic process that integrates process, people and the software platform, establishing a well-coordinated workflow among parties involved in a project [5]. Figure 1 depicts the intensity of BIM usage in different AEC processes in Germany based on a study [6].

Concerning academics, the abilities of entrants in the BIM relevant areas only, with the exception of the qualification in Computer-Aided Design (CAD), are rated as under average and not sufficient. The target or expectation in the industrial sector is to integrate technology with the technical and methodical aspects of the construction processes. For this purpose, the proposed project was developed to incorporate the technical knowledge gained through the course with real-time construction planning scenarios enabling the students to have a holistic understanding of the processes and execution adhering to it.

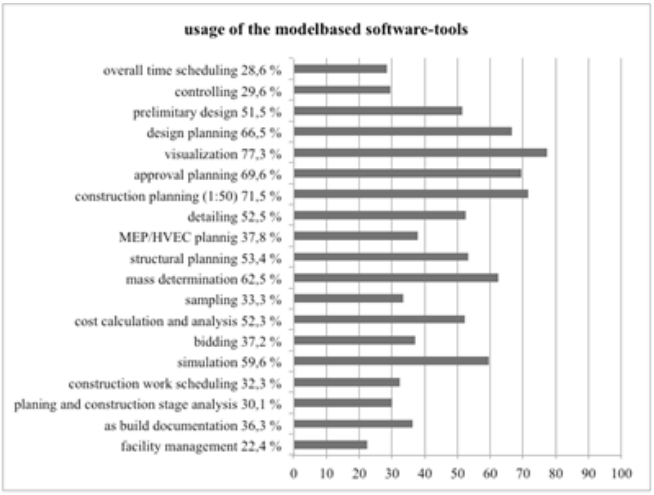


Figure 1: Usage of model-based software tools in different AEC processes [6].

2. Conceptualisation

The idea of the proposed project is to develop a task for the students of higher semester relating to real-time construction scenarios with the point of coverage on linking the theoretical and the practical aspects of the learned concepts in the course of piping technology and plant engineering. From this point of view, the presented project is to create a construction BIM model of a mechanical room in which the concepts learned in the course are to be implemented along with planning scenarios such as collision checks, the correctness of installed components and the addition of information to the BIM model in a structured way.

The aim of the proposed project is also to facilitate a practical understanding of the installation and uses of different components used in a Heating, Ventilation and Air Conditioning (HVAC) system, such as valves, pumps and heat sources, which the students have already learned in previous semesters of the course. It also aimed to improve the modelling skills with Autodesk Revit 2020 [4] software that is used to create digital twins of a construction project. The developed model can also be used to create an automatic bill of materials that would be a perfect practice for the procurement process that the students will encounter in a construction project during their professional careers.

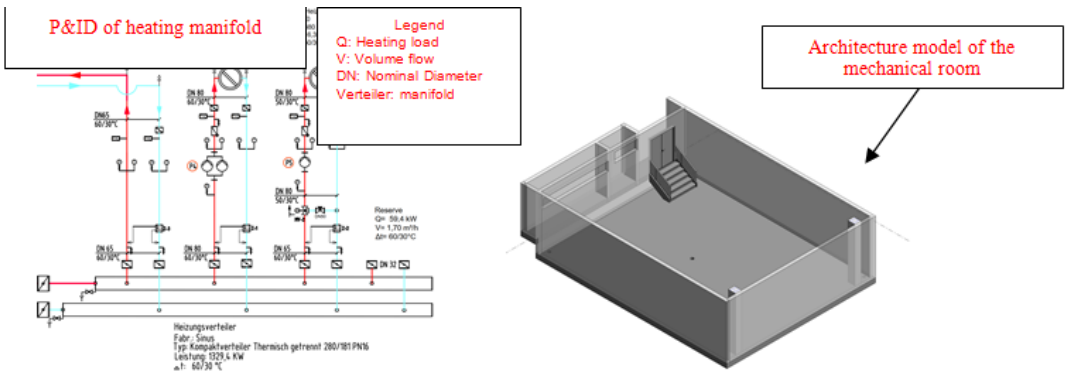


Figure 2: Piping and instrumentation diagram (left) and 3D view of the architecture model of the mechanical room (right) [Own representation].

To achieve this, documents such as piping and instrumentation diagrams (P&ID) with all relevant component-specific information and the architecture model of the mechanical room, as depicted in figure 2 have been developed and made available for the students. Furthermore, to implement learning by doing practice concerning the modelling software, demo videos have been created for specific tasks performed with the software, such as adding attributes, creating schedules, etc.

Subsequently, a 90 minutes presentation was made for the students explaining the importance of creating a construction BIM Model, correct installation of components in an HVAC system, the tasks to be performed and the execution and evaluation process of the presented project (figure 3).

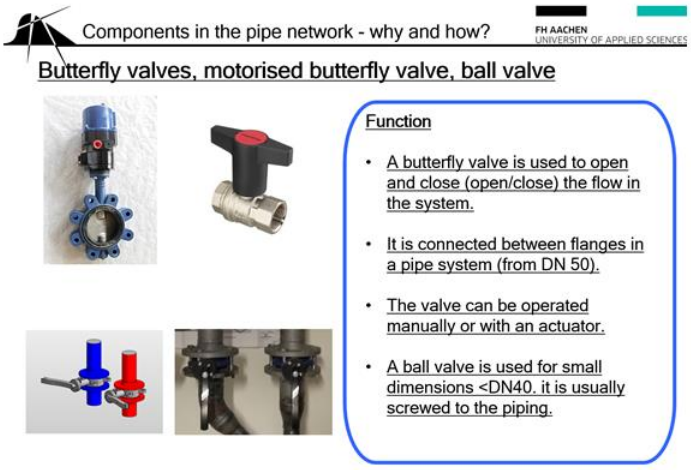


Figure 3: Screenshots from presentation depicting the correct installation of HVAC valves [Own representation].

The process workflow behind the conceptualization of the proposed project is depicted in figure 4.

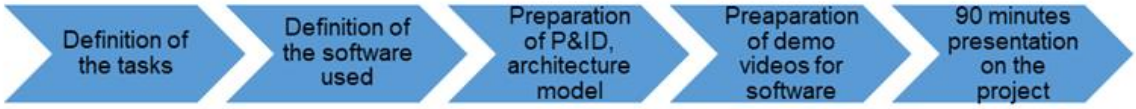


Figure 4: Process workflow behind the conceptualization of the proposed project [Own representation].

For evaluation, the Revit model with all relevant attributes, bill of materials for pipes, pipe fittings, valves, pumps and other components are to be considered.

3. Execution and results

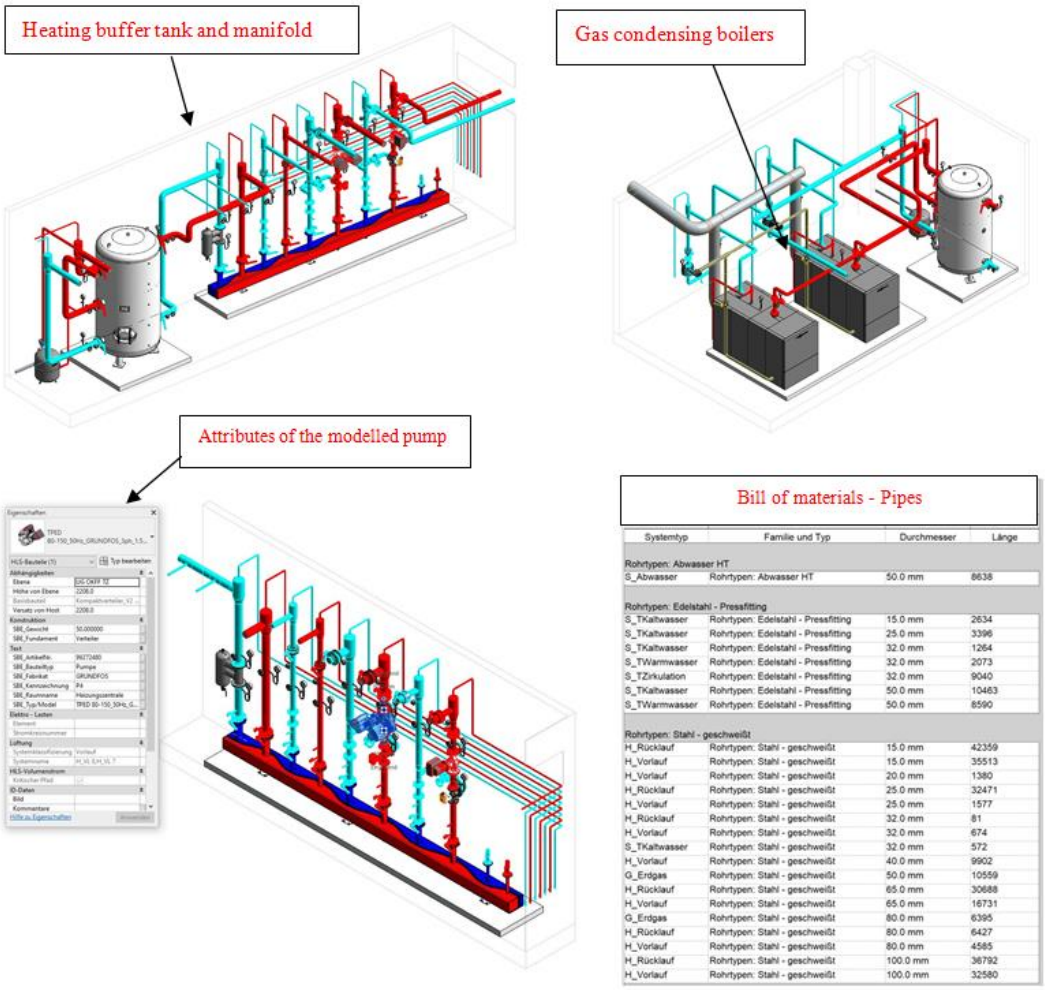
As a pilot phase, the project was implemented in the summer semester of 2021 as voluntary participation in the course of piping technology and plant engineering in the 6th semester of the bachelor's course smart building engineering at the Aachen University of Applied Sciences to understand the feasibility of the project. With this, the student were given an opportunity to get up to 30% of the allotted credits as a supplement for their final theoretical examination. The higher semester students formed five teams (each team with three members) independently and signed up for the project via E-Mail up to a deadline. The required documents and the task definition were made available via the ILIAS [7] platform. All teams could start their projects at once. The students had three months to work on the project and to put together a project folder with the required documents at the end.

The project presentation was realised digitally because of the extended corona restrictions during the lockdown in Germany at the beginning of 2021. In case of queries and problems regarding the project, the student groups were given an opportunity to contact the course supervisors and set up a digital meeting to find a solution together.

The results from the pilot phase (summer semester 2021) are depicted in figure 5. Even though it was a voluntary endeavour almost all the students participated enthusiastically.

Furthermore, the students on their own organised appointments with the supervisors to discuss the topic more in detail to get a comprehensive insight into real-time scenarios in the construction planning process of HVAC systems.

The submissions were graded, and all group members received the same grade for this project together. These points were added as supplementary in the main written examination for each participant.



Systemtyp	Familie und Typ	Durchmesser	Länge
Rohrtypen: Abwasser HT			
S_Abwasser	Rohrtypen: Abwasser HT	50.0 mm	8638
Rohrtypen: Edelstahl - Pressfitting			
S_TKaltwasser	Rohrtypen: Edelstahl - Pressfitting	15.0 mm	2634
S_TKaltwasser	Rohrtypen: Edelstahl - Pressfitting	25.0 mm	3396
S_TKaltwasser	Rohrtypen: Edelstahl - Pressfitting	32.0 mm	1264
S_TWarmwasser	Rohrtypen: Edelstahl - Pressfitting	32.0 mm	2073
S_TZirkulation	Rohrtypen: Edelstahl - Pressfitting	32.0 mm	9040
S_TKaltwasser	Rohrtypen: Edelstahl - Pressfitting	50.0 mm	10463
S_TWarmwasser	Rohrtypen: Edelstahl - Pressfitting	50.0 mm	8590
Rohrtypen: Stahl - geschweißt			
H_Rücklauf	Rohrtypen: Stahl - geschweißt	15.0 mm	42359
H_Vorlauf	Rohrtypen: Stahl - geschweißt	15.0 mm	35513
H_Vorlauf	Rohrtypen: Stahl - geschweißt	20.0 mm	1380
H_Rücklauf	Rohrtypen: Stahl - geschweißt	25.0 mm	32471
H_Vorlauf	Rohrtypen: Stahl - geschweißt	25.0 mm	1577
H_Rücklauf	Rohrtypen: Stahl - geschweißt	32.0 mm	81
H_Vorlauf	Rohrtypen: Stahl - geschweißt	32.0 mm	674
S_TKaltwasser	Rohrtypen: Stahl - geschweißt	32.0 mm	572
H_Vorlauf	Rohrtypen: Stahl - geschweißt	40.0 mm	9902
G_Erdgas	Rohrtypen: Stahl - geschweißt	50.0 mm	10559
H_Rücklauf	Rohrtypen: Stahl - geschweißt	65.0 mm	30688
H_Vorlauf	Rohrtypen: Stahl - geschweißt	65.0 mm	16731
G_Erdgas	Rohrtypen: Stahl - geschweißt	80.0 mm	6395
H_Rücklauf	Rohrtypen: Stahl - geschweißt	80.0 mm	6427
H_Vorlauf	Rohrtypen: Stahl - geschweißt	80.0 mm	4585
H_Rücklauf	Rohrtypen: Stahl - geschweißt	100.0 mm	36792
H_Vorlauf	Rohrtypen: Stahl - geschweißt	100.0 mm	32580

Figure 5: Isometric view of the heating distributor (top left), 3D view of the boilers (top right), 3D view of the pump with attributes (bottom left) and bill of materials for pipes [8].

In the current year, the project was again implemented for the summer semester of 2022 (pilot phase 2) with the integration of Air handling units (AHU) as an additional HVAC field to enhance coordination capabilities within Mechanical Electrical and Plumbing (MEP) disciplines among the students. Figure 6 shows the addition of the P&ID and the 3D model.

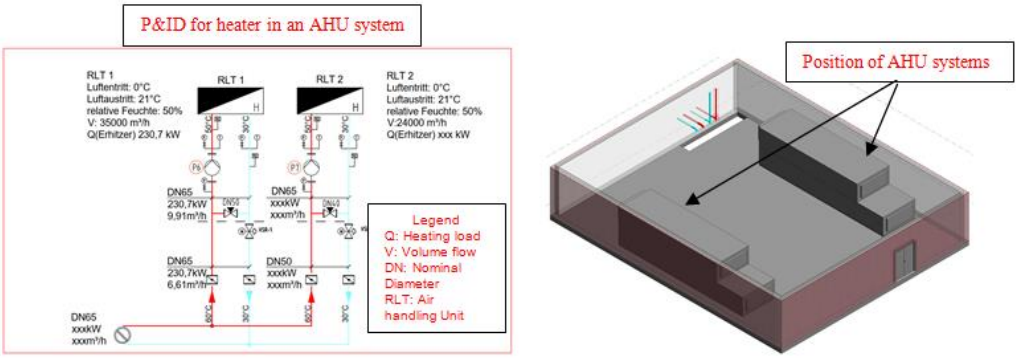


Figure 6: P&ID for heater in AHU system (left) and 3D view AHU Mechanical room (right) [Own representation].

4. Conclusion

Education lessens the challenges you will face in life. The more knowledge you gain, the more opportunities will allow individuals to achieve better possibilities in career and personal growth. In this sense, the future of education should be the right balance between theoretical studies and practical implementations according to the current industrial practices. The presented project was aimed to achieve this, and the pilot phase received positive feedback from the participated students. The students actively participated in the project even though it was voluntary and executed the work with minimal advisory requirements from the supervisors. This shows the furtherance among students for self-learning and practical implementations. The obtained results from pilot phase 1 were professional, which motivated the course organisers to execute it on a regular basis highlighting the need for integrating industrial practices with theoretical studies in the future of education.

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