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DIGITAL TWIN COLLABORATION: A COMMON TECHNICAL STRUCTURE FOR THE AUTOMOTIVE AND THE BUILDING INDUSTRY

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During the planning stage of production sites for the automotive industry, the building industry and the automotive industry clash. Nevertheless, the planning in both industries is generally done separately and there is not enough communication which leads to problems later on in the process. In the automotive industry, the digital twin is already used as a common tool for the planning and simulation of production lines. In the building industry however, the digitalization is not as well-advanced. Since the workflows, the degree of digitalization and the used software tools differ so much, the combination of the different processes and data of the automotive industry and the building industry is still very difficult nowadays. In order to solve that problem, the aim is to develop a common structure that allows both industries to collaborate and share their data, starting early on in the planning process. The current workflows of both industries were analyzed by conducting interviews with experts in their field. Evaluation of the answers and further discussion in the interdisciplinary team of the research project "CoLab4DigiTwin" showed that the workflows of both industries actually have the similar approach of starting the planning process by thinking in three-dimensional spaces that get more detailed information over time. Based on this finding, a hierarchical technical structure was developed, combining the spaces of the building industry and the automotive industry. This structure acts as a clear common base that facilitates an organized data exchange and improves the interdisciplinary collaboration.

Keywords: Building Information Modeling, Built environment, Collaboration platform, Sustainable interoperability, Plant engineering, Industry 4.0.

1 INTRODUCTION

Buildings are usually planned for a lifecycle of at least a few decades. Manufacturing plants on the other hand have to adapt more and more quickly to changing product needs on the market (Shivankar and Deivanathan 2021). As a result, production lines in the automotive industry are constantly planned and replanned using the Digital Twin as a common tool. Since these production lines are located inside of buildings, the automotive and the building industry inevitably come into contact with one another during the planning process. At present, this encounter often poses problems. In order to carry out the planning, the automotive industry is in need of data concerning the building – data which is often difficult to trace or even outdated since the digitalization in the building industry is not as well-advanced and depended on 2D-based communication for a long time (Eastman *et al.* 2011). Even though Building Information Modeling has become a widely used tool over the last two decades and is used more and more often during the planning of new buildings, existing buildings rarely have as-built digital representation (Volk *et al.* 2014). Building Information Modeling can be viewed as an approach to the Digital Twin (Deng *et al.* 2021, Radzi *et al.* 2023). However, the use of a real Digital Twin in the building industry is still at the very beginning (Opoku *et al.* 2021, Madubuike *et al*. 2022). Besides the different degrees of digitalization, the workflows and the used software tools in the two industries also differ. This is the reason why the combination of the different processes and data of the automotive industry and the building industry is still very difficult nowadays.

To solve that problem, the research project "CoLab4DigiTwin" aims to develop a digital collaboration platform based on the Digital Twin to improve cooperation and the data exchange in the sector of automotive plant engineering. Aside from the engineering, manufacturing and production data of the automotive industry, the data of the building industry will also be included. In order to reach that goal, the research project team consists of industrial companies as well as research institutes in the fields of automotive plant engineering, robotics, automation, software development, digitalization and construction. Thus, necessary experts are directly involved in the development of the desired solution. As a first step, a common base between the automotive and the building industry has to be established. This innovative concept will be presented in this paper.

2 METHODS

This paper aims to present a common organizational structure as a way to combine the processes and the data of the automotive and the building industry inside a future collaboration platform. In order to find a common ground, a deeper understanding of the approach and the workflow of each of the industries was needed. Experts in both fields were interviewed and presentations were held as to share the necessary information. The points discussed were the used software tools in each field, the used formats and the usual organization and workflow during the planning process. Once both fields understood the planning process of one another, further discussions in the interdisciplinary research team were held in order to pinpoint differences, similarities and difficulties and to work out the organizational structure.

3 RESULTS

The discussion and joint work in the team led to a better understanding of the respective fields. In the building industry, the planning process starts with a room book that includes the rooms of a building as well as their characteristics, like usage, dimensions and key figures. Using CAD-software, these rooms can be modeled as three-dimensional spaces as shown in Fig. 1.

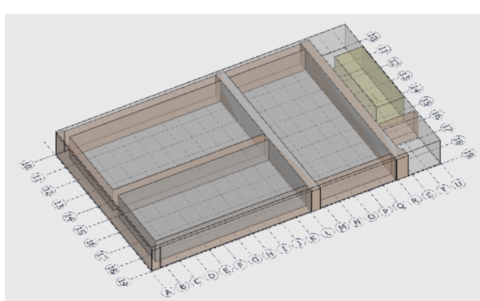

Fig. 1. Concept model in the building industry.

This method can be used not only to model actual rooms, but also to outline specific assigned spaces, for example for ducts or ventilation pipes. In the beginning of the planning process, these spaces are sufficient to visualize the concept of the building and to coordinate the needed spaces by the different participants involved in the building project. Over time, these spaces will then be filled with more detailed objects and further data.

In automotive plant engineering, the engineer usually gets a 2D-layout of the plant with marked areas in which the production lines can be planned. During the planning phase, the positioning of the needed machines is developed and digital objects like dummy robots are placed to demonstrate the amount of needed space. Once the planning gets more detailed, these dummy robots are replaced with digital representant of the robots that will actually be used in the plant. Furthermore, the areas assigned for the production lines are structured and subdivided in smaller, more specific areas. Fig. 2 provides a visual example of the dummy robots and the corresponding spaces in the automotive industry.

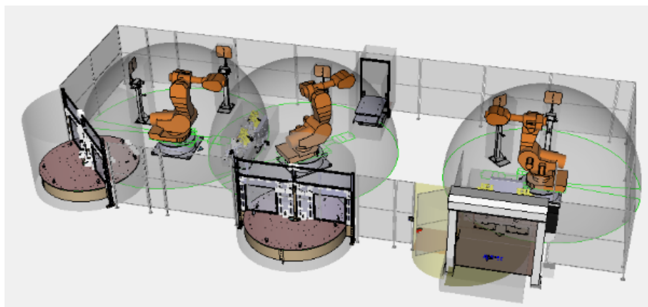

Fig. 2. Concept model in the automotive industry.

Combining these approaches of the two industries, the organizational structure model shown in Fig. 3 was developed. The organizational model consists of two layers, the planning process in the background and the technical structure in the foreground. In the following, these two layers will be explained in greater detail.

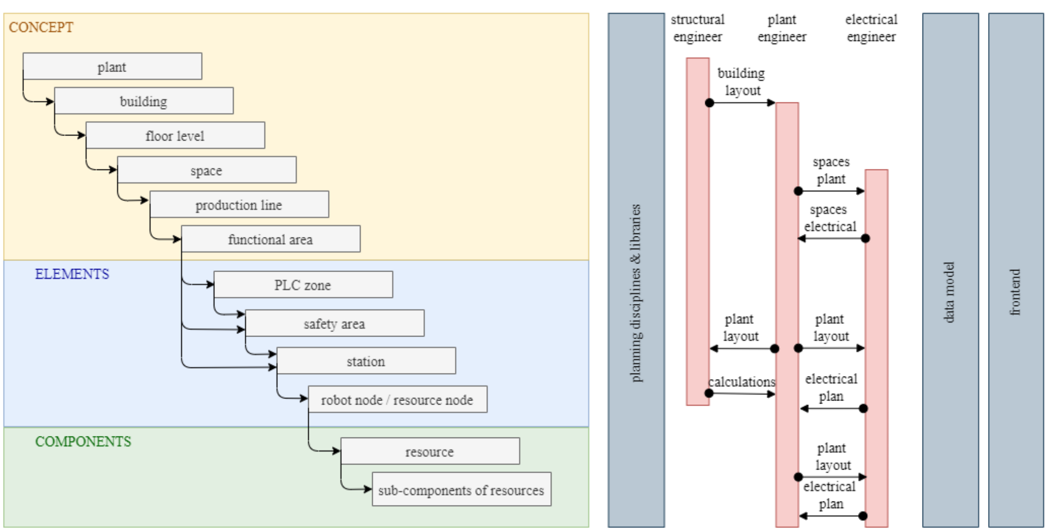

Fig. 3. Common organizational structure.

3.1 Planning Structure

The planning process consists of three phases: Concept phase, element phase and component phase.

3.1.1 *Concept phase*

The planning process starts with the concept phase. This phase lays the foundation for the following collaboration. As the interviews and the discussion in the team showed, the interdisciplinary cooperation during the planning stage of production sites for the automotive industry lacks communication and exchange, especially in the beginning. Often, both industries do their planning more or less separately which leads to subsequent problems. To change that, the approach of the building industry is used by developing a model containing the grid and the spaces for both the building and the plant. This digital model contains the main parts of the planned factory: buildings, traffic areas and production lines as three-dimensional spaces (*Hüllenmodell* (Böttcher *et al.* 2023)). With that, each planning team gets its assigned spaces to plan in and subsequent misunderstandings are reduced.

3.1.2 *Element phase*

During the element phase each planning team can proceed with its planning in the assigned space by placing the needed elements. These elements will be linked to the respective space. Elements describe objects that do not have specific attributes yet, for example a dummy robot that is placed inside a production line. The position and the space requirement of the robot can be displayed but the exact type of robot is not known yet. In case of need for more space or other plan amendments, one would go back to the digital concept model and modify it in cooperation with the other affected parties.

3.1.3 *Component phase*

In the course of the planning process, more and more choices are made concerning the exact type of objects. During the component phase, which represents the phase of execution, new information therefore can be added to the elements placed in the previous phase in order to store the necessary related data. Placeholder elements like dummy robots will be replaced by the actual type of object. Thus, the digital model with its data represents the 'as-built' state of the plant.

3.2 Technical Structure

Aside from the planning process, the building industry and the automotive industry follow a certain technical structure that is shown in the foreground of Fig. 3. The technical structure serves as a common base in order to navigate through the Digital Twin on the collaboration platform. The objects inside the Digital Twins will be linked to the hierarchical structure, making it easy to use and to find the needed information. This structure serves as the base for the planning disciplines, the data model and the frontend. In the course of the planning, the different planning disciplines share their data in the respective phase using library objects such as robots that will lean on the same structure of concept – elements – components. A robot in the concept phase for example will just be a representation of the three-dimensional space it occupies. In the element phase it will have a clearer three-dimensional representation and in the component phase it will have all the necessary information to identify it correctly.

3.2.1 *Technical structure in the building industry*

In the technical structure, the first three elements represent the building industry. A plant describes the whole property that can consist of a multitude of production lines. The building describes a structure in which a production is executed. The building is divided in usable, technical and traffic areas. Spaces describe areas inside the usable, technical and traffic areas. Spaces can contain production lines, but also fire protection requirements or emergency routes for example. In the course of the planning process, the building elements are placed in the Digital Twin and linked to the corresponding space.

The presented organizational structure model respects the two German standards DIN 277 and DIN 276 (DIN 2018, DIN 2021). In the DIN 277 "Areas and volumes in building construction", a building is divided in usable areas, technical areas and traffic areas. These areas are subdivided in smaller sectors such as production areas. The standard DIN 276 "building costs" structures a building into the two groups building construction and technical facilities. The building elements are assigned to these groups in order to calculate quantities and costs. As an example, the elements base slab, column or wall would be assigned to the building construction, electrical lines to the technical facilities.

3.2.2 *Technical structure in the automotive industry*

Following the hierarchical structure, the production line can be subdivided in different levels as well, as shown in Fig. 3. A production line is a space inside a building where a specific manufacturing task such as car body construction or assembly of parts is conducted. One manufacturing task is divided into multiple functional areas. The functional area consists of PLC zones, safety areas and stations. One PLC zone consists of one or more safety areas. All the components inside one PLC zone are controlled by one PLC (programmable logic controller). A safety area is often enclosed by a safety fence. In case of a violation of the safety area, at least all the components inside the safety area are shut down. A safety area consists of one or more stations; one station corresponds to one processing step of the product that is manufactured.

Robot nodes contain a robot and its attachments like robot consoles, tools, etc. In one resource node, multiple resources are grouped, e.g., a turntable and devices. A resource describes all the components of the production line such as a device, a conveyor, a rack. It is the central element during the operation of the production line. A resource can have more sub-components, e.g., a tool changing system.

4 DISCUSSION

Interviews and discussions in the course of the research project "CoLab4DigiTwin" revealed that nowadays, the communication and cooperation between automotive and building industry during the planning of production sites does not work trouble free. It could be identified that a big part of the problem was the lack of a defined common structure that combines the two industries from the beginning. Furthermore, the use of software tools and the Digital Twin in general differs a lot.

Despite the difference in the workflow and the degree of digitalization between the automotive and the building industry, a common ground for a future collaboration platform based on the Digital Twin could be found. The result was visualized in an organizational structure consisting of two layers – the planning process and the technical structure. Although the two layers are superimposed, the levels of the technical structure are not strictly assigned to the phases of the planning process, but the planning process is more an underlaying approach that might be used repeatedly during the planning stage.

5 CONCLUSION

In this paper, an organizational structure, developed by the interdisciplinary team of the research project "Collaboration for Digital Twin" was presented. This organizational structure combines the workflows of the automotive and the building industry and creates a common base for a future collaboration platform that is currently under development. The structure leads to a more organized data exchange and improved sustainable interdisciplinary collaboration.

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References

Böttcher, P., Baumann, P., Scheuern, M., and Wiggert, M., *Objektorientiert Planen und Bauen mit BIM*, bsD Verlag, Dresden, Germany, 2023. (in German)

Deng, M., Menassa, C. C., and Kamat, V. R., *From BIM to Digital Twins: A Systematic Review of the Evolution of Intelligent Building Representations in the AEC-FM Industry*, Journal of Information Technology in Construction, International Council for Research and Innovation in Building and Construction, 26, 58-83, March, 2021.

DIN, *DIN 276:2018-12: Kosten im Bauwesen*, Beuth-Verlag, Berlin, December, 2018. (in German)

DIN, *DIN 277:2021-08: Grundflächen und Rauminhalte im Hochbau*, Beuth-Verlag, Berlin, August, 2021. (in German)

Eastman, C., Teicholz, P., Sacks, R., and Liston, K., *BIM Handbook – A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors,* John Wiley & Sons, Inc., New Jersey, 2011.

Madubuike, O. C., Anumba, C. J., and Khallaf, R., *A Review of Digital Twin Applications in Construction,* Journal of Information Technology in Construction, International Council for Research and Innovation in Building and Construction, 27, 145-172, February, 2022.

Opoku, D. J., Perera, S., Osei-Kyei, R., and Rashidi, M., *Digital Twin Application in the Construction Industry: A Literature Review*, Journal of Building Engineering, Elsevier, 40, 102726, August, 2021.

Radzi, A. R., Azmi, N. F., Kamaruzzaman, S. N., Rahman, R. A., and Papadonikolaki, E., *Relationship between Digital Twin and Building Information Modeling: A Systematic Review and Future Directions*, Construction Innovation, Emerald, January, 2023.

Shivankar, S. D., and Deivanathan, R., *Product Design Change Propagation in Automotive Supply Chain Considering Product Life Cycle,* CIRP Journal of Manufacturing Science and Technology, Elsevier, 35, 390-399, November, 2021.

Volk, R., Stengel, J., and Schultmann, F., *Building Information Models (BIM) for Existing Buildings - Literature Review and Future Needs*, Automation in Construction, Elsevier, 38, 109-127, March, 2014.