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Model and data management issues in the integrated assessment of existing building stocks

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Abstract: The increasing population growth and urbanization rises the worldwide consumption of material resources and energy demand. The challenges of the future will be to provide sufficient resources and to minimize the continual amount of waste and energy demand. For the achievement of sustainability, increasing recycling rates and reuse of materials, next to the reduction of energy consumption has the highest priority.

This article presents the results of the multidisciplinary research project SCI_BIM, which is conducted on an occupied existing building. Within SCI_BIM, a workflow for coupling digital technologies for scanning and modeling of buildings is developed. Laser scanning is used for capturing the geometry, and ground-penetrating radar is used for assessing material composition. For the semi-automated generation of an as-built BIM, algorithms are developed, wherefore the Point-Cloud serves as a basis. The BIM-model is used for energy modeling and analysis as well as for the automated compilation of Material Passports. Further, a gamification concept will be developed to motivate the buildings' users to collect data. By applying the gamification concept, the reduction of energy consumption together with an automated update of the as-built BIM will be tested. This article aims to analyze the complex interdisciplinary interactions, data, and model exchange processes of various disciplines collaborating within SCI_BIM.

Results show that the developed methodology is confronted with many challenges. Nevertheless, it has the potential to serve as a basis for the creation of secondary raw materials cadaster and for the optimization of energy consumption in existing buildings.

Keywords: discipline models, data exchange, as-built BIM, Material Passports, resources and energy optimization

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1 Introduction

The demand for resources from nature is rising fast due to the expected population growth from 7 billion to 9 billion in 2050 (Programme des Nations Unies pour l'environnement, 2011). Accordingly, the increasing demands will lead to a significant amount of waste. Future challenges, therefore, will be dealing with the upcoming waste as well as the supply of sufficient land, material, and natural resources. As the construction sector is responsible for 60% of the raw materials extracted from the lithosphere (Bribián et al., 2011) and for 40% of energy-related CO_2 emissions (Dean et al., 2016), this sector requires optimization regarding resources and energy efficiency.

The building stock represents the largest material stock of industrial economies by being about as large as reserves of primary resources in nature on a global scale (Brunner and Rechberger, 2017), underlining the fact that it is of long-term importance to maintain or frequently recycle these urban stocks. Therefore, there is an urgent need for the development of applicable methodologies to build up knowledge of the existing stock. Since the existence of such knowledge would enable the assessment of the building stocks' performance and, moreover, enable analysis and prediction. For both, materials assessment and prediction and optimization of the energy demand, a BIM (building information modeling)-model is required.

BIM, as an emerging tool, has the potential to serve as a knowledge basis for follow-up material and energy assessments since its potential for life-cycle optimization of buildings has already been recognized (Fellows and Liu, 2012). BIM enables modeling, analysis, and optimization regarding resources and energy efficiency of new constructions as well as of the building stock. Through coupling BIM with scanning methods such as laser scan and ground-penetrating radar (GPR), a thorough assessment of existing stocks can be conducted. Moreover, inventories on the detailed material composition of buildings, such as Material Passports (MPs) and simulations regarding energy consumptions, can be generated. The BIM-based coupling of digital technologies for modeling and analysis has large potentials to support both reduction of the resources consumption and of the energy demand.

In this article, the results of the ongoing funded research project SCI_BIM "*Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling*" are presented. The research project received funding from the Austrian Ministry for Transport, Innovation and Technology through the Austrian research promotion agency FFG (Österreichische Forschungsförderungsgesellschaft). The project aims to increase both the resources and energy efficiency of buildings. Therefore, technologies and methods for capturing and modeling (as-built BIM with geometry and material composition) of buildings are coupled. By applying the gamification concept, users are integrated into the process of updating the as-built BIM-model.

2 State of the art

At present, buildings consume >35% of the energy worldwide and are responsible for about 40% of global CO_2 emissions (Abergel et al., 2017). Due to worldwide rapidly increasing consumption of resources and population growth, dealing with resource scarcity is and will continue being a challenging task. To overcome these obstacles, some strategies, such as "Urban Mining," already exist. Urban mining proposes to reuse or recycle the existing stocks to minimize the use of primary resources and thus decrease the extraction of raw materials. However, to apply the urban mining strategy, it is necessary to have detailed knowledge about the existing stock and incorporated materials—a knowledge that is currently lacking. Another strategy is introduced by the European Union's (EU) action plan for Circular Economy (CE), which proposes to increase recycling rates to minimize the consumption of raw materials, the upcoming of waste and environmental impacts. CE aims to reach a resource-efficient and low carbon economy by maintaining the value of materials and resources in the economy as long as possible (European Commission, 2015). The achievement of the EU goals 20-20-20 lies in the existing stocks and less in new constructions since the rate of new constructions is only 3% (Euroconstruct, 2018). However, the lack of comprehensive knowledge on the exact material composition of the existing building stock is still the main obstacle for a prediction of future material flows as well as the increase of recycling rates. Even the assumptions of the energy performance of the existing building stock mostly build up on statistical analyses or energy passes following time categorization.

The application of digital technologies, such as BIM, offers extensive advantages in resource management (Figure 1). BIM, as an emerging tool in the Architecture, Engineering and Construction (AEC) industry, has the potential to serve as a knowledge database and moreover

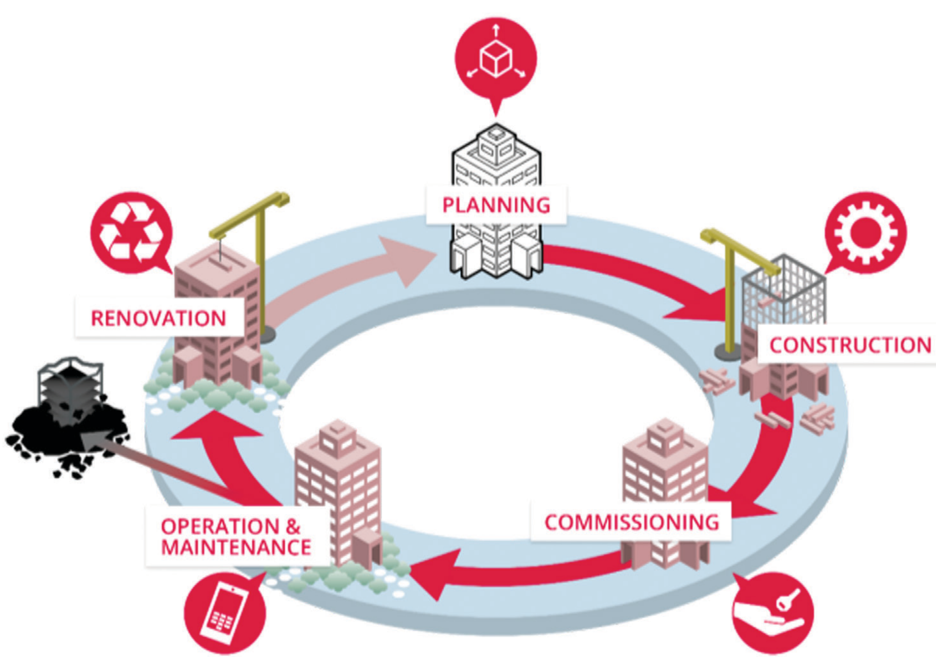

Fig. 1: The life cycle of a building (https://hydronic-flow-control.com/en/page/our-services--building-life-cycle).

it enables modeling of building elements including materials information and quantity determination (Eastman et al., 2011; Bazjanac, 2006, Azhar, 2011). BIM allows applying a life cycle perspective on facilities and construction projects. At the end of the life cycle, the demolition of an object, stands the waste management, which benefits from a data model with a wealth of information. The challenge for using BIM technologies lies especially in digitizing the current building stock and thereby making it accessible to the life cycle orientated management in accordance with the BIM philosophy. However, such methods of capturing are very elaborate, and thus, the comprehensive data collected by the laser scan and GPR should be most widely used. The BIM models, which are enriched with the exact geometry and material properties, should, therefore, serve not only as a basis for the material cadaster but also for the life-cycle analysis and optimization.

The geometry of existing building stocks is increasingly being assessed by laser scanners, depending on the purpose of the resulting point cloud in color or monochrome. The point cloud obtained from the registered scans can either act as the basis for an accurate to the millimeter line evaluation or can be processed into a photorealistic 3D model, such that it is not only available for planners and architects but also to the populace. A single scan can generate up to millions of 3D points. The laser scanning technology enables the follow-up generation of as-built BIMs. For the structure of a model, the examined building has to be scanned from different positions to finally merge the generated point cloud into a model, which is currently possible only with a semi-automated process. The generated point cloud can be converted into triangular surfaces, which, however, cannot be transformed directly into BIM objects. When modeling the BIM, the following tasks have to be solved: (1) the geometry of the components must be defined ("Which shape does the wall have?"); (2) categories and materials have to be assigned to the components ("This is a brick wall."); and (3) relationships and connections between the objects must be established ("Wall 1 is connected to Wall 2 and is located on the second floor").

Thereby, the current state-of-the-art generation of as-built BIMs from point cloud or voxels is still a mainly manual, time-consuming, and error-prone process. Although there are already numerous methods and technologies for capturing data of as-built BIMs, these focus mostly on the gathering of geometry—the gathering of the material composition is currently little explored (Figure 2).

In this research project, the gamification approach within the BIM environment will be tested through user-participation. The gamification approach arises from the game industry and is useful for buildings, where it is not possible or too expensive to install sensors. Merschbrock et al. (2014) tested the implementation of gamification through user participation in the design stage of a building. Rüppel and Schatz (2011) applied gamification to simulate the user behavior during a case of fire.

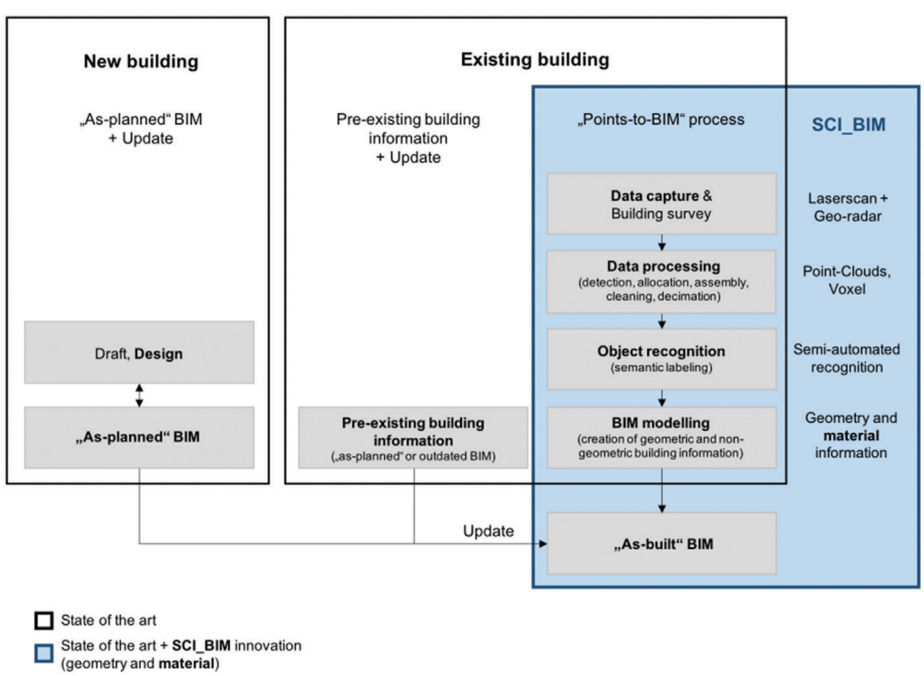

Fig. 2: Comparison of the state-of-the-art as-built BIM data processing and SCI_BIM integrated data assessment and modeling method (based on Huber et al., 2011 and Volk et al., 2014).

In SCI_BIM, gamification is used to document the "as-is state" of the building as well as to implement the user behavior.

In our previous research, we developed a BIM-based MP, which documents the material composition of a building (Honic et al., 2019). The MP serves as a planning and optimization tool even in early planning phases with regard to the efficient use of materials and subsequent demolition, as documentation for the recycling of buildings and as the basis for an urban material cadaster at the city level. The methodology developed for BIM-based MPs is very well applicable and serves as a basis for "SCI-BIM." The acquired know-how can be further deepened in "SCI-BIM" and extended through the integration of energy efficiency aspects as well as user-participation within the gamification approach, which is tested on a real use case.

3 Problem statement

The construction sector needs optimizations regarding energy and resource efficiency since it is the sector with the highest consumption of raw materials and moreover consumes >35% of the worldwide energy (Dean et al., 2016). To analyze and optimize the existing stock, on the one hand, it is necessary to have material information for enabling recycling of the materials in the stock, on the other hand, it is necessary to optimize the energy consumption of existing buildings. Currently, there is a lack of knowledge on the material composition and construction of building stocks, which represents a major obstacle for increasing recycling rates on the city-level (Brunner, 2011), as well as for the optimization of the energy consumption of buildings. Research about the existing stock shows that, for many materials, the secondary stock is even larger than the primary resources, for example, Austria—a country that strongly depends on imports. In many European countries, the situation is similar to Austria: due to a low amount of primary resources, an import of raw materials is necessary (Brunner and Rechberger, 2017).

In this article, a research gap, which is the comprehensive modeling of material composition and geometry of existing buildings, based on capturing data by scanning is addressed. Since new construction rate across Europe is only about 3%, including residential, nonresidential, and civil engineering sectors, this article focuses on the existing stocks (Euroconstruct, 2018). The capturing and modeling of buildings' geometry is already well explored; however, methods for capturing and modeling of materials embedded in buildings in combination with the geometry of buildings are largely lacking. In particular, this article focuses on the analysis of complex interdisciplinary interactions and data exchange processes of various disciplines collaborating within the proposed SCI_BIM process-design: planners, surveyors, computer graphics, and software developers, and the handling of their respective discipline-specific models and data. Further on, the user-participation issues within this digital ecosystem and the employed incentive mechanisms will be addressed. Required interactions between the stakeholders, data exchange challenges, and the workflows will be analyzed.

The objective of this article is to build up a methodology for the integrated assessment of the material composition and for the optimization of the energy consumption of buildings. Therefore, a framework will be generated, which shows the data flows, interactions between the involved stakeholders and the processes in between. Moreover, the applicability of the developed methodology on a larger scale will be discussed. The main research question is, if by coupling of laser scan- and GPR-technology for follow-up BIM-model generation and creation of discipline models for assessing the material and energy efficiency, as well as the application of gamification, an integrated assessment of the existing stock is possible.

4 Methodology

This research builds up on the interactions of various disciplines, such as planners, surveyors, computer graphics, and software developers, and the handling of their respective discipline-specific models and data to generate an "as-built" model, which serves as material inventory and as an energy optimization model. The basis for this article is the research project SCI_BIM, which is conducted at Vienna University of Technology in collaboration with Faculties for Civil Engineering (TU-IBAU, TU-FAR), Architecture (TU-BPI, TU-DAP), and Computer Science (TU-VC) and the central institution for meteorology and geodynamics—ZAMG Archeo Prospections (ZAMG), as well as industrial partners—two engineering survey companies C1 and C2. Throughout the research, an integrated data assessment and modeling method are developed and tested in a real case.

The methodology, as shown in Figure 3, is tested on a building of an institute of Vienna University of Technology. The use case is a single-story industrial building with a typical construction out of reinforced concrete, whereby the exterior walls are cladded with a corrugated sheet. The

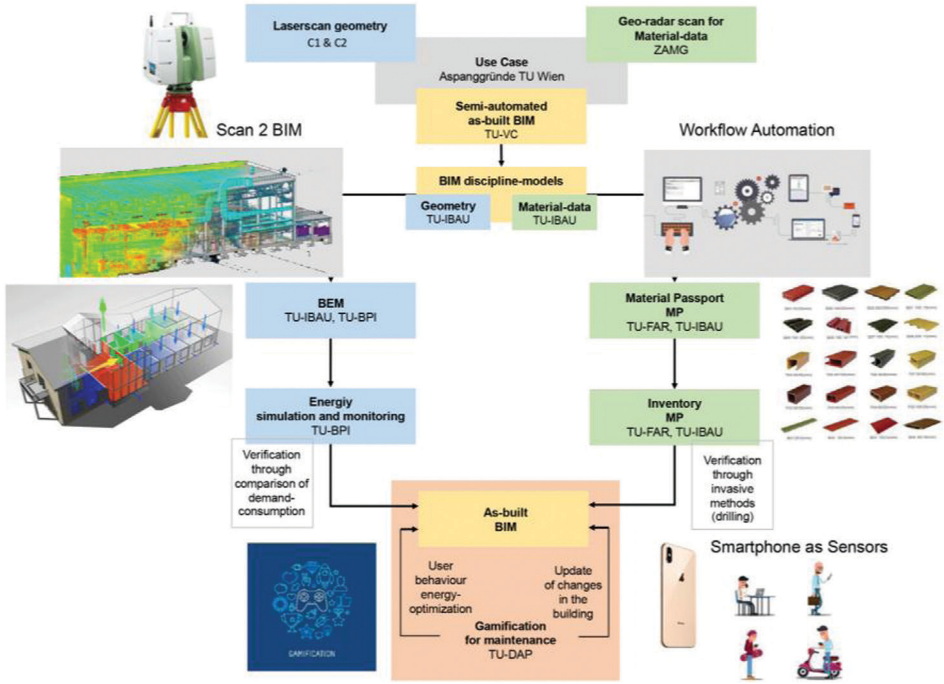

Fig. 3: Process design.

building consists of three main parts, which also vary in their height: the storage has an area of 560 m^2 at a height of 6.85 m, the office including communal facilities has an area of 275 m^2 at a height of 3.8 m, and the lab part extends over an area of 430 m^2 at a height of 5.9 m. Throughout all surveys, the building was occupied by the users.

The first step in this research was scanning the use case to obtain the geometry and material composition of the building. The geometry was determined through laser scanning (by C1 and C2) and the material composition through GPR scans (by ZAMG). Thereby C1 was using a very precise point cloud with large data size (high-tech), whereas C2 is using a low-tech variant with lower data size and cost.

The second step, after the creation of the point cloud, is the generation of a BIM-model. The generation of a BIM out of a point cloud is confronted with many manual steps. In this research, the development of a semi-automated process will be tested. Thereby, the first task, as mentioned in the Section 3, is the automated recognition of surfaces and objects through algorithms. After the recognition of surfaces, an automated generation of BIM objects and consequently of the entire BIM-model should be enabled.

In the third step, discipline models are created for further energy assessment on the one hand and for material assessments on the other hand, after the generation of the BIM-model. For further energy assessments, a simplified model is required, whereby for material assessments and follow-up generation of a MP, enrichment of the model through data obtained from ZAMG (GPR scan) is necessary.

In the next step, two disciplines (energy and material assessments) are working on their specific models to generate results for energy demand and resource consumption of the building. Thereby, the aim is to optimize the energy demand and to generate a MP for the building, which shows the detailed material composition and the recycling potential of the building.

The final step is to gather all data in one model—“as-built” BIM—which is the digital twin of the existing building. Changes in the building, as well as user behavior, are tracked by user participation through applying a gamification concept. Thereby, the users of the building are connected to the model through a smartphone app, through which they track changes in the building and collect data of the building.

The actual energy demand will be verified through a comparison of the predicted energy demand with the actual consumption. The real material composition will be verified through invasive methods such as drilling as well as through surveying by demolition companies, which are commissioned to conduct a contaminant investigation in any case for demolition objects. Invasive methods are possible since the building will be demolished in the near future. The entire process, from scanning to the final "as-built" model, is accompanied by a cost–benefit analysis to evaluate the tested methodology and determine the more feasible variant (high-tech or low-tech, costs) for application on a larger scale (e.g., city level).

5 Data and process management framework

The overall aim of the project is to increase the energy and resources efficiency through the coupling of technologies and methods for capturing and modeling (as-built BIM with geometry and material composition) an existing building. Finally, using the gamification concept, the as-built BIM-model is being updated. However, the generation of the as-built BIM-model and the maintenance of the model by continuous update are challenging tasks. The process requires a step-by-step data exchange between the various disciplines and the participation of the users. Figure 4 displays the workflow steps: (1) data gathering, (2) pre-processing, (3) model creation, (4) post-processing, and (5) data maintenance.

- **Data are gathered** by the surveyors (C1, C2, and ZAMG) through scanning the use case from different positions inside and outside the building. Thereby, the geometry is determined through laser scanning (by C1 and C2) and the material composition is determined through GPR-scans (by ZAMG). C1 is conducting a very detailed data collection of the geometry using an expensive handheld scanner (device A). C2 tested three different devices for scanning: a high-cost

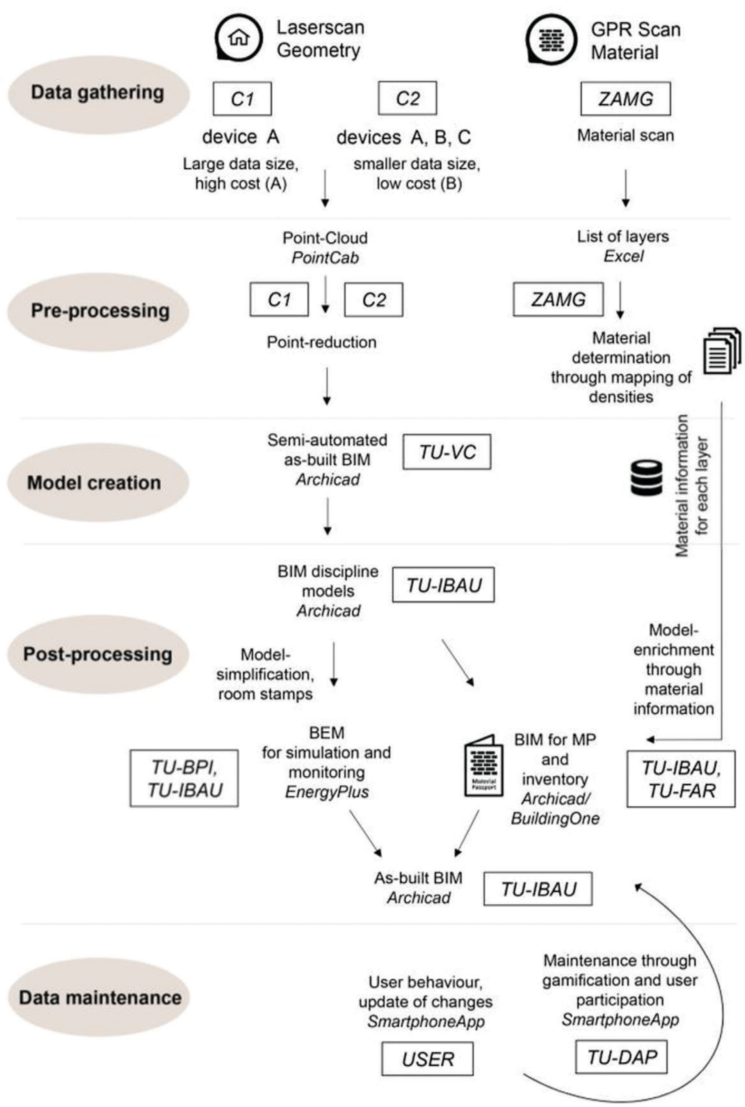

Fig. 4: Data and process management framework.

handheld scanner (device A), a low-cost terrestrial laser scanner (TLS) scanner that runs on a tablet (device B), and a depth camera (device C). Device A is the most expensive one, followed by device B and finally C. After testing the devices, device C was not considered in the project further, since scanning took too much time even for a small room and moreover the obtained results were not valuable. For that reason, for further research and scanning of the use case, only devices A and B were used. As C1 also uses device A, C2 focused only on device B for the further steps. Both devices generate point clouds, whereby device A creates more detailed point clouds with higher amount of data than device B, which means that C1 tests the high-tech variant and C2 tests the low-tech variant. With device A it was possible to scan the whole building with only 4 scans, whereby with device B 90 scans were conducted to obtain the whole geometry of the buildings' interior. The difference in the amount of scans is reflected in the required scanning-time: the scanning time of the high-tech variant required only one-fourth of the time which the low-tech scanner needed for scanning the whole building. The materials composition of the elements is determined by using a GPR. The scanning with GPR was conducted in three stages, since it was not possible to scan all building elements due to furnishing. The GPR sends and receives electromagnetic waves and as a result it creates an image of the received waves and their energy.

- After scanning, **pre-processing** of the point cloud starts. The created point clouds are registered and joined to one representative point cloud of the whole building. In the next step, the point reduction is conducted in PointCab (PointCab, 2019), whereby unnecessary data, such as furniture inside the building and trees in the surrounding, are removed. ZAMG uses GPR to scan the building components and defines their material composition. The identification of the materials occurs through mapping the determined densities (through GPR) with those from a materials list out of a material inventory. First, the results of the measurements showed that a mapping of densities will not work since the obtained result from the scan is an image of the received electromagnetic waves, from the walls and slabs. The GPR can distinguish between two different materials with a varying density, but cannot define the material composition immediately. Therefore, the interpretation of the data is required to define the possible material composition of a building element. However, some rough material compositions of elements were defined, which enable data handling in GIS and the export of an Excel sheet for further use for the MP.
- The **model creation** is conducted manually and semi-automated based on the obtained point cloud. The surveyors create the manual model by using Archicad (Graphisoft, Archicad 2019). Therefore, the point cloud is imported into Archicad and serves as base for the manual modeling of the building components. The manually created BIM-model by C1 is the reference model and represents the basis for all other models. C1 and C2 are both generating a manual BIM-model for the use case, though building upon two different point clouds. C1 is using a very precise point cloud with large data size, whereby C2 is using the low-tech variant with lower data-size. The investigation of the differences between the created models regarding quality and time-effort, is part of the cost–benefit analysis, as mentioned in the Section 4. The semi-automated generation of the BIM is conducted by TU-VC. Based on Huber et al. (2011) and Volk et al. (2014), as illustrated in Figure 2, a semi-automated generation of the BIM-model in Archicad was tested. However, as the research project is still ongoing, there are no results of this part of the process yet.
- After the BIM-model has been created, the model is **post-processed** by two different disciplines to create on the one hand a building energy model (BEM) (TU-BPI and TU-IBAU) and on the other a BIM for MP (TU-IBAU and TU-FAR). For further energy simulation and prediction, a simplification and post-processing (e.g., adding of room stamps) is required to prepare the model for the EnergyPlus Software (EnergyPlus, 2019). To create a MP for the building, the material information from ZAMG has to be assigned to the components of the BIM-model in Archicad, which is a manual process, conducted by TU-IBAU. For the integration of materials' information to the BIM-model, an automated process will also be tested by TU-VC. For the compilation of the MP, the BuildingOne (OneTools, 2019) tool is used, where also the final MP-document is created. For the generation of the MP, MP-relevant parameters (e.g., recycling potential, environmental impacts, etc.) are assigned to the materials and quantities obtained from the BIM-model. As BuildingOne is an Add-On in Archicad and has a bi-directional interface to Archicad, there are no challenges regarding data exchange. The final as-built BIM merges the energy model and material information together to one model, which represents the as-built model and is maintained through the gamification app.

- **Data are maintained** by tracking the changes in the building (e.g., static data: removing an inside wall) and by constantly updating the BIM-model. Besides the static data, also dynamic data are being tracked: for example, the state of a window (opened/closed/tilted) or the lightning (switched on/off), such that the tracked data are also used as a basis for energy optimization. As for the optimization of the energy efficiency of a building, the user behavior plays a crucial role, the user behavior is tracked through user participation. Therefore, TU-DAP is creating a smartphone app, through which users are connected to the as-built model and supply the app with the required information (e.g., window open or closed; the wall has been removed, etc.). The automated update of the as-built BIM-model is enabled through the connection of user participation with the BIM-model, which is one of the big challenges of this research. Therefore, the required data formats have to be defined, and the smartphone app has to be developed.

6 Applicability of the methodology on a larger scale

The high- and low-tech variants are assessed and compared regarding their applicability on a larger scale. Therefore, a cost–benefit analysis is carried out, in which the two variants are assessed and compared. Since the project is still ongoing, the cost–benefit analysis is not complete yet. The high-tech variant requires higher costs for the acquisition of the device (A), thereby producing a high-quality point cloud with large data amounts. The low-tech variant involves the usage of a less expensive device (B), thereby producing a point cloud with lower data size. The generation of the BIM-model is based on the created point cloud, whereby it will be analyzed, if the high- or low-tech variant is more efficient for an automated BIM-model generation. The high-tech variant might be more efficient since a high-data amount would lead to a faster BIM-model generation and accordingly to a more accurate model. There is also the possibility that the high-tech variant leads to an overload of data due to the required time for pre-processing. The disadvantage of the low-tech variant might be the inaccuracy of the point cloud and time effort for pre-processing. The advantages of the low-tech variant are the low costs for the device and fewer data processing if the obtained data are sufficient. On a large scale, the costs for pre-processing of data are significant, since the costs will accrue each time a building is being scanned and a BIM-model generated, whereby on the contrary, if an expensive device is bought once, it can be used for many buildings and the costs will not add up.

7 Results

The results show that the created methodology based on the coupling of technologies and methods for capturing and modeling (as-built BIM with geometry and material composition) enables the integrated assessment of the existing stock. A fully automated methodology is not possible due to different obstacles such as insufficient data collection and occupancy of the building, as described in the next section. The cost–benefit analysis, which will be completed at the end of the research project, will show if the low- or high-tech variant is better applicable on a broader scale such as city-level.

The main challenge within the whole process was the occupancy of the use case throughout the data gathering stage. The occupancy leads to difficulties in accessing all elements, and moreover, the users of the building were disturbed in their daily praxis by scanning. For laser scanning, the occupancy was not such a big challenge as for the materials detection by ZAMG, since ZAMG could only scan building components that were free from furniture. The comprehensive analysis of all walls by ZAMG requires many scanning stages. Another limitation of the data-gathering stage was the accessibility of the building. In our research, the building was easily accessible from three sides, since there is no building closely next to it. However, the southwest facade of the building is surrounded by a slope and trees, which made the access difficult. Apart from the accessibility, an overload of data was identified as another challenge (Figure 5). Since the building was surrounded by trees and other buildings (far away) as well as occupied and furnished during the laser scanning phase, an effortful reduction process was required (Figure 6). Due to the mentioned overload of data, uncertainties occurred, as it was difficult to determine, for example, if a scanned object is just furniture or part of the building in the point cloud. Therefore, it is difficult to verify if the modeled BIM is 100% correct, such that a comparison of the various BIM models (C1 and C2), existing plans, and on-site observations are necessary. As user participation is necessary to keep the BIM-model updated, the user participation is linked to the gamification app, which motivates the users to participate in the process through the distribution of little prices for certain achievements (e.g., first person that recognized a change

Fig. 5: Point cloud of the use case and the surrounding (© C1).

Fig. 6: Panorama of the interior of the use case (© C1).

in the building and entered it in the app). However, there still exists the risk that the intended workflow does not work in every use case if the users are not willing to participate. In the pre-processing stage, the obtained data from ZAMG require further interpretation, since the output data are an image of the electromagnetic waves received from the radar antenna which does not give any information about the exact material composition.

8 Conclusion

This article presents the results of the research project SCI_BIM. The innovation of this project is the coupling of laser scanning and GPR technologies as well as methods for modeling to obtain an as-built BIM of an existing building for follow-up assessment and optimization of the energy consumption and recycling potential. The research was conducted on a real use case, which is an occupied building of Vienna University of Technology. For capturing the geometry, laser scanning-technology (hand-held scanner and terrestrial laser scanner) was used to obtain the Point-Cloud and BIM-model in the next step. To determine the material composition of the use case, GPR technology was applied, which delivered building components after the interpretation of the image of the electromagnetic waves.

The main result is the developed methodology for the integrated assessment of the material composition as well as for the optimization of the energy consumption of buildings. Therefore, a data and process management framework, displaying the core tasks of each discipline as well as the software and data exchange interfaces for all stages by starting with data gathering, followed by pre-processing, model creation, post-processing, and finally concluding with data maintenance, has been created. The main challenge within the workflow was identified as handling of the discipline-specific models and data. Other challenges, such as the fact that the building was occupied throughout the scanning period which required further scanning tasks, the motivation of the users to participate in the gamification process, as well as the data overload through scanning, and lack of interdisciplinary knowledge were faced. To enable smooth data and information exchange, it is crucial to determine the data exchange formats and their interfaces by conducting team meetings before each step. Another result is the conducted cost–benefit analysis, which evaluates the developed methodology from scanning to generation and maintenance of the as-built BIM regarding time-effort and costs, by comparison, a low- and a high-tech variants. Apart from that, the cost–benefit analysis tests the applicability of the developed methodology for generating secondary raw materials cadaster on the city-level and assesses its feasibility. As the research project is still ongoing, the cost–benefit analysis is still not complete.

By application of the developed methodology on other use cases, extensive information on the existing stock can be obtained. The existence of comprehensive information could serve as a basis for a secondary raw materials cadaster, which displays the embedded materials on, for example, city-level. On a macro-economic scale, the existence of a secondary raw materials cadaster could increase the recycling of valuable materials in the stock, thus decrease the dependency on imports of primary materials. Moreover, the accordingly generated secondary raw materials cadaster would enable the generation of a digital platform, where the obtained information could be embedded in order to make it available for the public.

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