A Decision Support System for the Building Permit Review Process

Judith Fauth and Sebastian Seiß

***Abstract*—Obtaining a building permit is an indispensable factor for a successful construction project. However, from a project management perspective, it is a non-transparent and subjective variable. There is a gap of assistance for the building application review in the building authorities. The approach aims to develop a decision support system for building permit review process from a project management's point of view. For this purpose, the requirements for a decision support system related to the building permit are identified. To convert the theoretical system into a practical solution, a web application is developed. The presented approach thus offers an alternative to automated rule checking. The decision support system makes the building permit process more objective and transparent.**

***Index Terms*—Decision support system, building permit, code compliance checking, process modeling, building application review.**

I. Introduction

The building permit is essential for a successful construction project. To approve a building permit, several decisions are needed. This regards the design phase conducted by planners as well as the assessment of the building permitability by the building authorities. Based on the decision-making theory, certain factors are required to make a decision as objective as possible.

Obtaining a building permit is still a variable in a construction project that is difficult to calculate [1]. The processes are primarily non-transparent and error-prone [2]. From a project management perspective, there is a particular gap of decision support for building permit review in the authorities.

Despite valuable approaches to automated code compliance checking (ACCC) in building law, these procedures have not yet been able to establish themselves across the board. Reasons for this are that not all regulations and scenarios can be reviewed automatically [3], [4] and that social acceptance for fully automated administration is missing [5]. In addition, the automation of individual case decisions, such as a deviation, has an unrealistic cost-benefit ratio [5].

The presented approach looks for a solution to check building permits from the project management perspective. The main focus is on the performance-based, qualitative regulations and individual deviations. These aspects need to be checked manually, while other approaches consider automated checks of quantitative regulations. To manage such complicated issues a decision support system is proposed. The decision support system targets the support of plan reviewers, strengthen objectivity and transparency in the overall approval process.

After introducing the topic background, the research problem statement, and the own approach in section I, section II provides background information about previous work, interdisciplinary basics and related work. The system development description is given in Section III, followed by a case study in Section IV and a discussion in Section V. The paper closes with a summary and conclusions in Section VI.

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The authors are with the Department of Construction Engineering and Management, Bauhaus University Weimar, Thuringia, 99423 Weimar, Germany (e-mail: judith.ponnewitz@uni-weimar.de, sebastian.seiss@uni-weimar.de).

II. Background

A. Project Management, Process Management, and Decision-Making

Construction project management is responsible for the standardized handling of construction projects and is applied in all phases of a construction project. Project management is implemented through processes. The processes selected for a particular project should be coordinated from a systemic point of view [6]. Process management is thus an important complementary subarea of project management.

Processes for building permit determination have been scientifically studied rather superficially so far. Reference [7] compared countries in the European Union to determine, for example, whether simplified procedures exist in the respective country or what role inspection after construction completion plays. A study from Italy shows the process there concerning the interaction between the applicant and the local authorities [8].

Reference [4] structured the actual building permit review processes by the plan reviewer into different levels and included both formal and material information. Fig. 1 shows five main processes of building permit review and a breakdown of subprocesses (levels). An example of the evolution of these process levels is shown in Fig. 2. [9] describes a detailed conformity review. Conformity review is understood to mean the examination of the content of the individual regulations. In the process, the plan reviewer is presented with various process alternative.

It can be seen that a variety of decisions must be made during the building permit review process. Decision theory states that essential elements must be present to make a decision: objectives, process alternatives, and influencing factors, as illustrated in Fig. 3.

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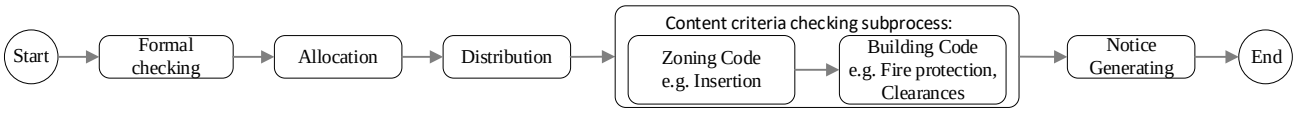

Fig. 1. Major processes of building permit review (according to [4]).

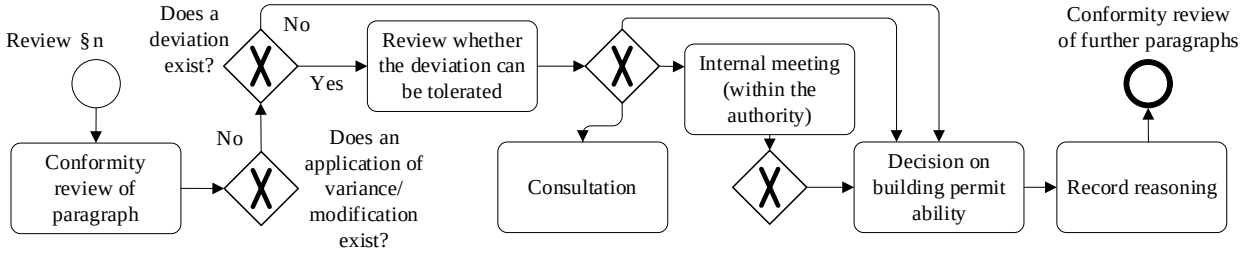

Fig. 2. Extract of building permit conformity review [9].

Influencing factors describe all factors that affect the decision but cannot be influenced by the decision-maker. Decision models represent an aid to decision-making. These do not dictate the decision but support the decision-making process and serve as a preparation for the decision [10]. It needs to be noted that the targeted decision support system is not the same as an expert system. While the decision support system represents information, an expert system represents knowledge. Knowledge can predefine a decision, i.e., interpret it from existing information. In order to build up such knowledge, information about decisions has to be collected and processed.

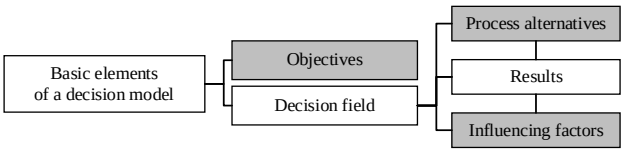

Fig. 3. Basic elements of decision model (according to [10]).

B. Legal Situation

The content of building law can be devided into qualitative and quantitative content. In the context of qualitative content, the term performance-based building regulations is to be found, while in the sense of quantitative content, the term prescriptive regulations is used [11]-[14]. The inclusion of both qualitative and quantitative statements in the law's text is to be considered necessary in this context [15].

Since not every individual case can be clearly described in building regulations, the use of performance-based building regulations is to be considered advantageous. They are more responsive (in terms of the state of the art) without compromising legislative aims and ensuring simpler application [12], [13]. At the international level, the trend in the formulation of building codes is toward performance-based (qualitative) building codes rather than prescriptive (quantitative) building codes [13], [14].

The challenge of implementing automation is amplified by the current legal situation in different countries, which does not accept the decisions of third parties, including machines [16]. Especially in German law, it is hard to deal with automation in individual cases regarding discretional action. Discretion means the freedom to decide what should be done in a particular situation. Not every case or eventuality can be written in law texts, and this is why discretion is proposed by law but makes automation even more difficult. Discretion especially applies to individual decisions or deviations. In the process, deviations frequently occur during a building application. Deviations can be submitted to the authority with a justification and sometimes also with an offered compensation [4]. Here, it is to speak of a case-by-case consideration.

C. Technological Issues

Model checking or Automated Code Compliance Checking describes an automated check of regulations based on a BIM model. Geometric, semantic, and linked information is checked for compliance with building regulations, for example. The main challenge is the translation of the regulations into a computer-interpretable language [17]. To check a model, model checkers are used as a special software tool.

According to [18], just objective clauses can be checked automatically regarding to code translation issues. The following situations imply an individual manual check by an expert, as shown in Fig. 4:

1) deviations already requested in advance or in combination with the submission of the building application
2) non-objective clauses cannot be checked automatically [3], [11], [18].
3) model checking software determines errors or noncompliance.

The research has shown that research approaches have technical and legal limitations. Fig. 5 illustrates that manual expert check in terms of subjective decisions is outside the previous research scope. Due to the nature of building codes, ACCC can be well applied to prescriptive building codes (with quantitative content), but only partially (17% according to [3] applied to performance-based building codes (with qualitative content). Further, other building codes have neither a prescriptive nature nor characteristics of a performance-based building code [12]. In addition, there is an unknown number of deviations, modifications and variances that have to be considered individually (both illustrated in light grey in Fig. 5).

D. Examples from Practice and Academia

In international practice, only a few countries are working with BIM-based files in building permit authorities so far.

Singapore is a pioneering example. The country assumes a pioneering role in building permit review, not least due to the BIM application that has already permeated the construction sector for decades [19]. The CORENET e-Plan Check application performs the conformity review using a BIM model based on Industry Foundation Classes for a large part of the Singaporean building regulations [19], [20]. The verification is performed using the black box method [21]. A black box stands for a software application whose procedures cannot be seen. Accordingly, the user only sees input and output values. In contrast, the white-box method describes an application that makes all elements and processes that lie between the input and output values visible and comprehensible [21]. Requested deviations are still discussed in person [11], [22].

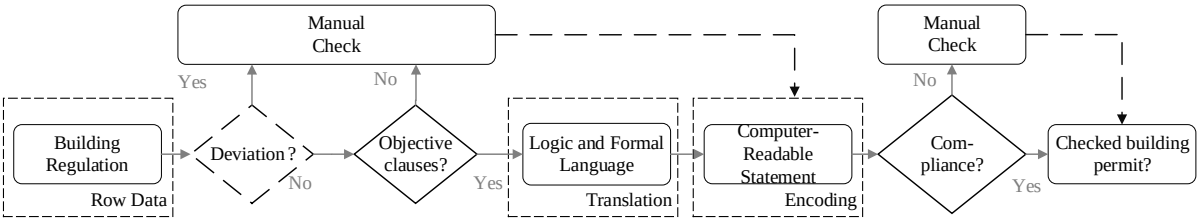

Fig. 4. Schematic checking process of one regulation (according to [18]).

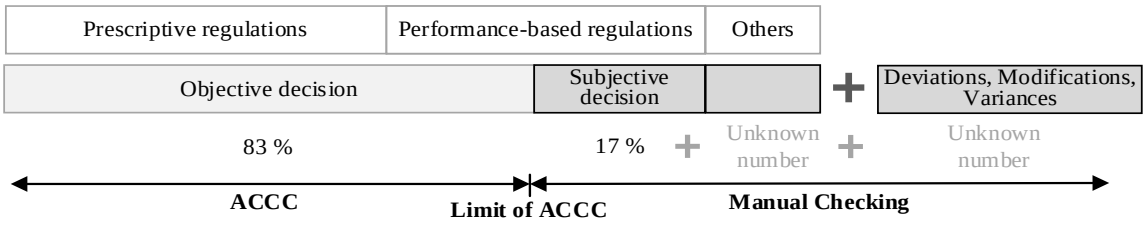

Fig. 5. Schema of the regulation-decision ratio of ACCC and manual checking.

The German research project "BIM-basierter Bauantrag (BIM-based building application)" aimed to create solutions for a BIM-based building application. The topic focuses on the semi-automated creation and review of BIM-based building applications for selected regulations within a development plan. This included the development of a BIM-based web platform and a modeling guideline. Information regarding deviation requests is provided using BIM Collaboration Format (BCF) [23], [24]. The BCF is a data exchange standard to exchange problems and errors by comments and pictures related to the BIM.

The practice shows that web-based platforms are already in use by the building permit authorities. Nevertheless, the manual review is not considered yet.

III. System Development

A. Concept

The development of a decision support system is divided into five steps, shown in Fig. 6. In the first step, requirements are established based on decision-making theory. In the second step, a general schema of a decision model for building permit review is developed. The general schema is transformed into a specific schema with technical considerations in step 3. In step 4, a prototype web application is presented. An extension of the web application into a BIM software takes place in the step 5.

B. Requirements and a General Building Permit Decision Support System

Before a decision model can be developed, its requirements must be identified and defined. For this purpose, the requirements are subdivided into the categories of user requirements and system requirements.

The system requirements are oriented decisively to the necessary elements for a decision: aims, processes and influencing factors. In terms of the building permit review, the following requirements are specified:

- Aims: objective of each regulation in planning and building code, specified by legislation
- Process definitions: all processes that can be used in the process of determining the building permitability as well as their alternatives
- Influencing factors: information and data that influences the decision but cannot be influenced by the decision maker, e.g., legal text, information and documents related to the specific construction project (e.g. protocols, planning documents, BIM models), mandatory software used by the specific authority.

The user requirements focus all requirements regarding the user. The following aspects should be considered:

- Intuitive user interface: promises user acceptance even for non-IT-specialists
- Non-proprietary format: vendor-independent platform because of the difficulty of the authorities to favorize a specific software
- Information support: system requirements at the precisely assigned place inclusive documentation fields for reasoning and commenting
- Export possibility of decisions and reasoning made: opportunity of data collection and analysis outside the system
- Connection to other data: domains to connect (e.g., BIM model, protocols, results of model checkers)
- Extensibility: further decision support can be incorporated like automated checks.

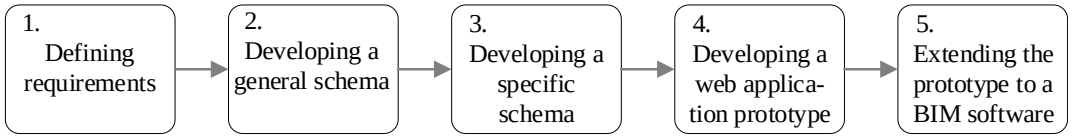

Fig. 6. Concept steps of system development.

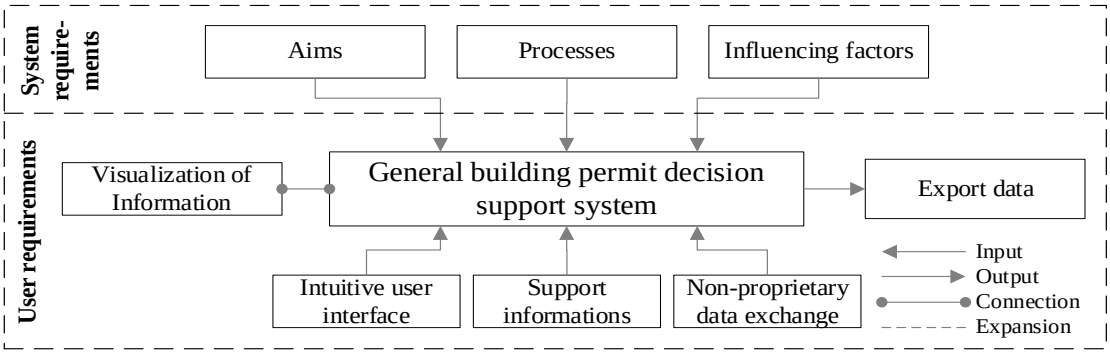

Fig. 7. General schema of building permit decision support system.

Based on the defined requirements, Fig. 7 illustrates a schema of a general building permit decision support system. All elements are linked to the system as input, output, connection or expansion relationships.

C. Development of a Specific Building Permit Decision Support System

To meet all requirements, especially considering the intuitive usability a web application is chosen as technology. A web application seems particularly suitable due to the requirement of a non-proprietary interface. This means that no BIM software is directly integrated into the system. In addition, objects cannot be directly linked to aims. An aim is associated with a paragraph and objects are associated with a paragraph. This states an application outside of a BIM software as a valuable extension.

Fig. 8 shows a specific schema of a building permit decision support system web application. The previously identified requirements are specified in it. Besides, internal and external elements are added to the specified system. All internal elements (e.g., aims, processes) are to be regarded as general. This means that they are established across projects in the web application (illustrated in white color in Fig. 8). The goals of the legal texts do not change depending on the project. The external elements are project-specific (illustrated in grey color in Fig. 8). They are provided to the user separately for each construction project. Examples are the building application documents and the BIM model.

For better illustration, Fig. 9 shows a screenshot of the developed interface of the web application. It is shown which elements have which function.

IV. Case Study of Embedding the System in a Software

The previous sections describe the functionality and the application of the developed web-based building permit decision support system. At this stage, the system does not support the use of a BIM model. However, in order to be able to use the potential of the BIM method and the functionalities of various BIM-based software solutions, the developed prototype of the web application can be integrated into these solutions. The combination of BIM-based software functionalities and the building permit support system enables the plan reviewer to check visually the construction project, query or filter the BIM model for required information and use ACCC functionalities.

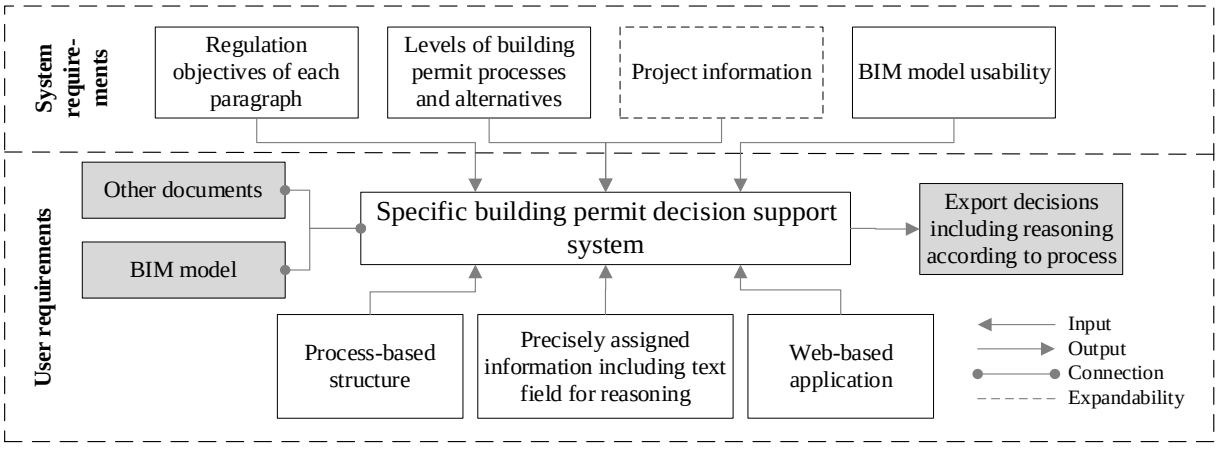

Fig. 8. Schema of building permit decision support system using web application technology.

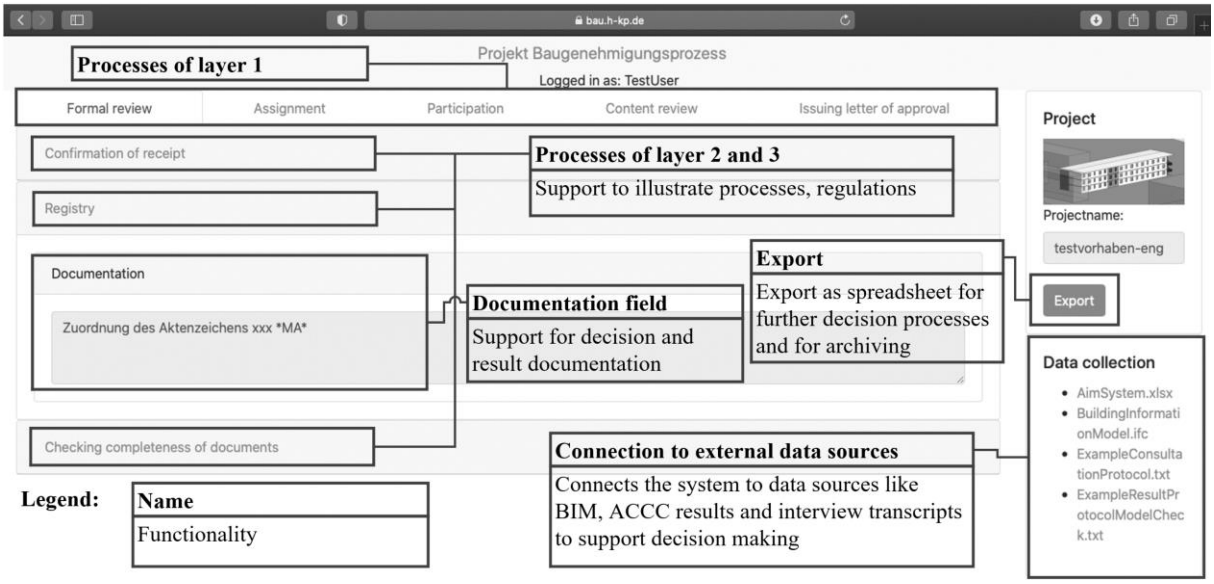

Fig. 9. Examples of functionalities on web application interface (screenshot).

Furthermore, a connection of external software solutions by the web application supports the building authorities' neutrality requirement and avoids complex reimplementation of functionalities in the web application.

In order to evaluate the application of the web-based building permit decision support system in the BIM environment, the web application is embedded in an exemplary BIM software. For this example, the software Desite md [25] were chosen. The connection was made by using an Inlineframe (iFrame) within the document module of Desite md, which allows to use Hypertext Markup Language (HTML) and JavaScript. An iFrame enables a simple and quick mirroring of the content from other web services with the respective application based on a standardized HTML-function. Due to the fact that this solution is a mirroring of the HTML-based web application within the software, the user serves as an interface between the applications. As can be seen in Fig. 10, the communication between Desite md and the web application is done by the user. In future, an application programming interface (API) will support this interface functionality of the user between the applications. The API will be able to transfer object-IDs, views and checking results to improve the documentation related to the regulations. The decision itself and its reasoning have to be still done manually.

The embedded web application in Desite md can be seen in Fig. 11. The user has full and direct access to the model and its object information. Furthermore, the user can access functions such as measurement tools, queries/filters and implemented rule checks. The findings obtained in this way can be entered immediately into the web application. The web application supports the user to follow the building permit review process and the documentation of the results. In addition, Desite md makes it possible to export checking results via BCF and to upload them via the export button integrated in the web application user interface. In this way, the documentation is object-oriented and can be accessed in the data collection in a comprehensible way. Not only building authority employees can be seen as users of this platform, but also applicants or their representatives can use the platform within their modeling software. This allows the applicant to understand the process and assess the approvability of their application.

Fig. 10. Example implementation/usage of the prototype in Desite md.

V. Discussion

The proposed approach provides the plan reviewer with a standardized workflow for checking performance-based regulations and handling deviations. Decisions are made conscious to the plan reviewer as such, which increases objectivity in the whole process. The plan reviewer, is supported by necessary information needed to make a decision. To increase transparency, the plan reviewer is provided with action alternative and documentation options for its justification, which are subsequently output in a structured manner. With the collection of data, a basis is laid for further investigations.

The approach also makes the process more transparent and objective for the applicants. If the respective specific model processes are publicly available to the applicants, they are able to adapt and prepare their application documents accordingly.

With the choice for a web application, an intermediate solution is offered that gently introduces the plan reviewers to the digital transformation and BIM. This is because the solution is based on current processes and familiar technical applications, which can be used before automated checks from other approaches can be implemented in a further step. In principle, the web application can be used immediately as a decision support tool, as it does not identify legal (e.g., application of discretion) or technical obstacles (e.g. vendor neutrality). Besides that, it is a cost-effective solution (no costly software licenses or hardware are needed for the authorities) and can be adopted to different legal systems in other countries.

Object information	**BIM model**	**Web application**
Illustration of alphanumeric object and model information	Visualisation of the BIM model. Usage of integrated software tools like measuring to check code compliance	Predefined process steps, access to rule-specific explanations and documentation of decisions

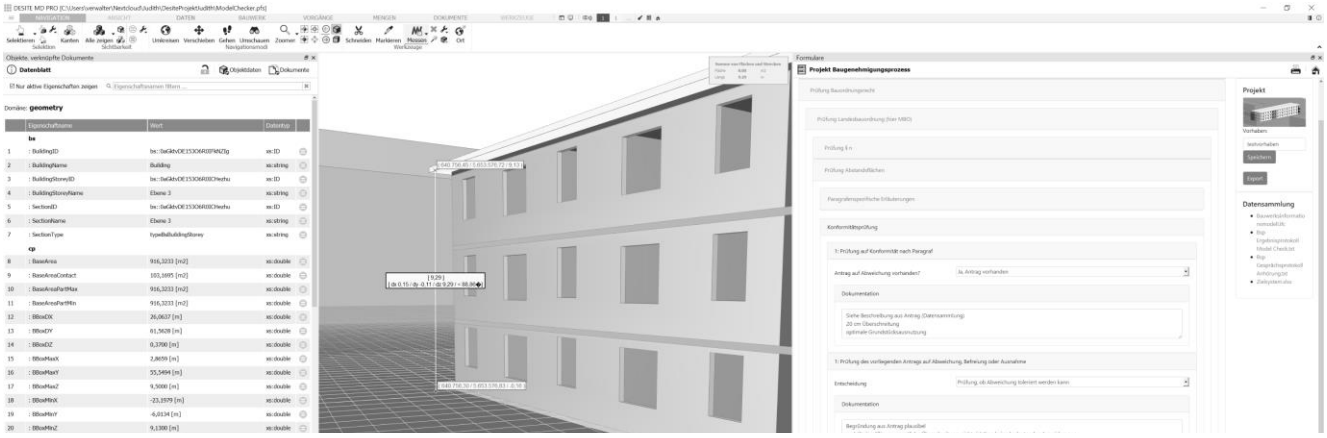

Fig. 11. Example of usage the prototype in Desite md.

VI. Summary and Conclusions

Previous approaches focus on the development of automated solutions for building permit checks. These solutions can not cover all regulations and situation (e.g., non-by-right cases). A part of the building permit reviews will remain manual. But also, manual checks can be supported.

The proposed paper describes the development of a decision support system for the building permit review. The system aims at supporting transparent decisions within the building application review and provides a standardized handling of the building permit processes in a building authority. The decision support system takes the form of a web application that provides all the necessary information for the plan reviewer. In doing so, the approach focuses on the requirements of project and process management as those of information technology. The system thus represents a supplementary solution for regulations and situations that cannot be checked automatically. Furthermore, it serves as an alternative solution to automated checks for non-IT-specialists.

Future studies focus on a validation in building authorities at an international level starting in fall 2021. Besides investigating the user acceptance, plausibility, and other aspects, a first step towards using the exported data for a data base related to a knowledge representation will be considered. Moreover, the development of the web API is a further research activity which the authors aim.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Fauth conducted the research while Seiß implemented the platform in Desite md. Fauth wrote the section I-III and V–VI and Seiß the section IV. Both authors had approved the final version of the paper.

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J. Fauth was born in Germany in 1987. She has received her bachelor's degree in architecture in 2012 and her master's degree in facility and real estate management in 2014.

She is currently a PhD candidate at the Bauhaus University Weimar in Germany and worked as a Research Associate at the chair of construction engineering and management between 2015 and 2019. Ms. Fauth research interests are in the area of building permitting related to digitization and decision making. She is a member of the European Network for Digital Building Permit (EUnet4DBP).

S. Seiß was born in Germany in 1992. He graduated as M.Sc. in construction management at the Bauhaus-University Weimar on the chair of construction management under Prof. Dr.-Ing Hans-Joachim Bargstädt in 2018.

He works at the chair of construction management at Bauhaus University Weimar (Germany) as a research assistant since 2019. Also, he started working for the 5D-Institut at Gießen (Germany) in 2020 as senior consultant. His research interests are data management and data processing in the construction execution phase with the focus on construction quality management.