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The BIM-Based Building Permit Process: Factors Affecting Adoption

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Abstract: Public organizations responsible for building permits are increasingly considering the potential applications of Building Information Modelling (BIM) in their workflows, but BIM adoption still remains a complex challenge. This research aims to investigate the factors affecting BIM adoption for building permits through a case study of a public organization currently developing and piloting a BIM-based building permit process. A thematic analysis of semi-structured interview data revealed ten factors that influence BIM adoption for building permits: complexity (in both development and use) of a BIM-based building permit system; relative advantages/disadvantages of BIM for building permits; the existing building permit system; management support for a BIM-based building permit process; organizational culture; BIM awareness; training and learning; available expertise for a BIM-based building permit process; external pressure; and legal context. The findings are important for public authorities' understanding of both the enablers and challenges of the BIM-based building permit process, and have practical implications for professionals in public authorities in particular, and also the Architecture Engineering Construction/Facilities Management (AEC/FM) industry in general, to guide their steps towards adopting BIM. This research also highlights the potential benefits of BIM adoption for the building permit process.

Keywords: building permit; Building Information Modelling; BIM adoption; building regulatory authorities; case study; thematic analysis

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1. Introduction

A building permit is necessary to initiate construction projects, particularly in urban areas. It is an official document granted by public authorities that gives permission for the commencement of construction works (to build new or make changes to an existing structure) in accordance with the relevant laws, regulations, and codes. Permits are also required for reconstructing or demolishing a building. The issuance of building permits is considered to be one of the indicators for measuring a country's business [1] and a major component of the institutional factors that influence the success of construction projects [2]. In addition, the building permit process plays a vital role in the efficient use of land, and is necessary for ensuring building safety and quality, as well as achieving sustainable and smart cities [3].

Obtaining a building permit involves a complex process with a large number of stakeholders, several steps, and, in many countries, this process is still analogue, with the information exchanged in paper format. In some countries, the information is handled through e-submission of digital files, such as pdf and dwg. The existing building permit process is considered to be subjective, prone to human error, time consuming, difficult to track, and unpredictable due to ambiguous regulations [4]. Inefficient building permit procedures result in delays to the overall construction process. Rapid urbanization has also led to an increased demand for constructing new buildings, and this has added pressure on local regulatory authorities by increasing the number of building permit

applications. In response, public authorities are adopting BIM to facilitate the exchange of information between stakeholders, and make the overall process more efficient. BIM is "a digital representation of physical and functional characteristics of a facility, and a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle" [5]. As a revolutionary technology for effective information management and collaboration, BIM offers an important opportunity for municipalities to handle building permits more efficiently.

A BIM-based building permit process enables the submission of BIM models instead of 2D drawings, and offers the possibility of automated code compliance checking instead of manual reviews. Currently, the use of BIM in the building permit process is not widespread, but municipalities in some countries, such as Singapore, Finland, and Norway, have taken solid steps towards integrating BIM in the building permit process [4]. In addition, in recent years, a number of studies have been carried out to examine the potential use of BIM for building permits, for example, Olsson et al. [6], Kim et al. [7], and Ciotta et al. [8]. These studies have introduced different prototypes and frameworks for BIM-based building permit processes, but there has been relatively little research on how public regulatory authorities can successfully implement them.

Though a BIM-based building permit process offers potential advantages, BIM adoption itself is a complex phenomenon affected by many factors that may be considered from multiple (e.g., technological, organizational, external) perspectives. Investigating the factors affecting BIM adoption can play a vital role in designing a framework for successful adoption of BIM by organizations, and a number of studies have examined factors impacting BIM adoption in the AEC/FM industry generally [9–11]. There is, however, a lack of research to date that systematically investigates the factors that affect the BIM-based building permit process. To help fill this gap, this research is focused on examining the factors affecting BIM adoption by public authorities for their building permit process. This study investigates the case of the Tallinn City Government (TCG), a public organization responsible for building permits in Tallinn, the capital city of Estonia.

A literature review to describe the principal concepts of the BIM-based building permit process and factors affecting BIM adoption is reported in Section 2. The methodology used in this study is explained in Section 3, and followed by the case study description in Section 4. The findings of the study are reported in Section 5, and discussed in Section 6, before conclusions are drawn in Section 7.

2. Background

This section introduces the role of BIM in the building permit process, and factors that affect BIM adoption in the AEC/FM industry.

2.1. BIM and Building Permits

BIM, as an innovative technology, has become very popular in both the construction industry and in academic research, particularly in the last decade, as it offers promising advantages and applications for construction activities. It is believed that BIM has changed the way construction projects are conceived, designed, constructed, and operated [12,13]. The concept of BIM as a comprehensive information database anchored to a digital model is central to BIM use in the building permit process.

Shahi et al. [4] categorized the development of building permit systems in a four-level framework. Level 0 represents the traditional permit process which is based on the submission of physically transmitted papers by applicants and their manual review in municipalities. Level 1 refers to basic e-permit systems, in which 2D drawings and other files are submitted in digital form (rather than paper documents) through a web interface, and then there is a manual review of those digital files by authorities. Level 2 refers to BIM use in the permit process. Instead of digital 2D drawings, a comprehensive BIM model of a facility can be submitted, and then automated code compliance checking takes place. Level 3 is described as the future of the permit process, with full integration of BIM and GIS

into the building permit system, so that a building is not only analyzed as an individual object, but also evaluated in the context of its urban setting and its relationship with nearby buildings. The potential integration of geoinformation with BIM for the building permit process is investigated by Olsson et al. [6] and Noardo et al. [14].

In a typical BIM-based building permit process, as shown in Figure 1, the applicant submits building information models, usually created by the designer. Since BIM adoption among architecture firms is already quite considerable, this phase in the development of a BIM-based building permit system is not particularly challenging, although certain additional requirements and guidelines must be set for model submission to ensure the compatibility/correctness of the models for the building permit process. On the authority's side, the building model is then checked against laws and regulations through an automated code compliance checking approach in order to make a decision. If the design and other details in the digital building model satisfy the terms and conditions defined in laws and regulations, the building permit is granted. Automated code compliance checking requires translating the rules and regulations from their natural language to computer readable format. According to Olsson et al. [6] and Preidel and Borrmann [15] due to technical and legal constraints, this is one of the main difficulties in developing BIM-based building permit systems. Several studies, including those by Nawari and Alsaffar [16], Malsane et al. [17] and Lee et al. [18] have investigated the technical aspects of code compliance checking, presenting different methods (for example, artificial intelligence and mark-up language) to facilitate the translation of laws and regulations to machine-readable formats. In general, BIM-based building permit processes are considered to be efficient, user friendly, highly accurate, and achievable.

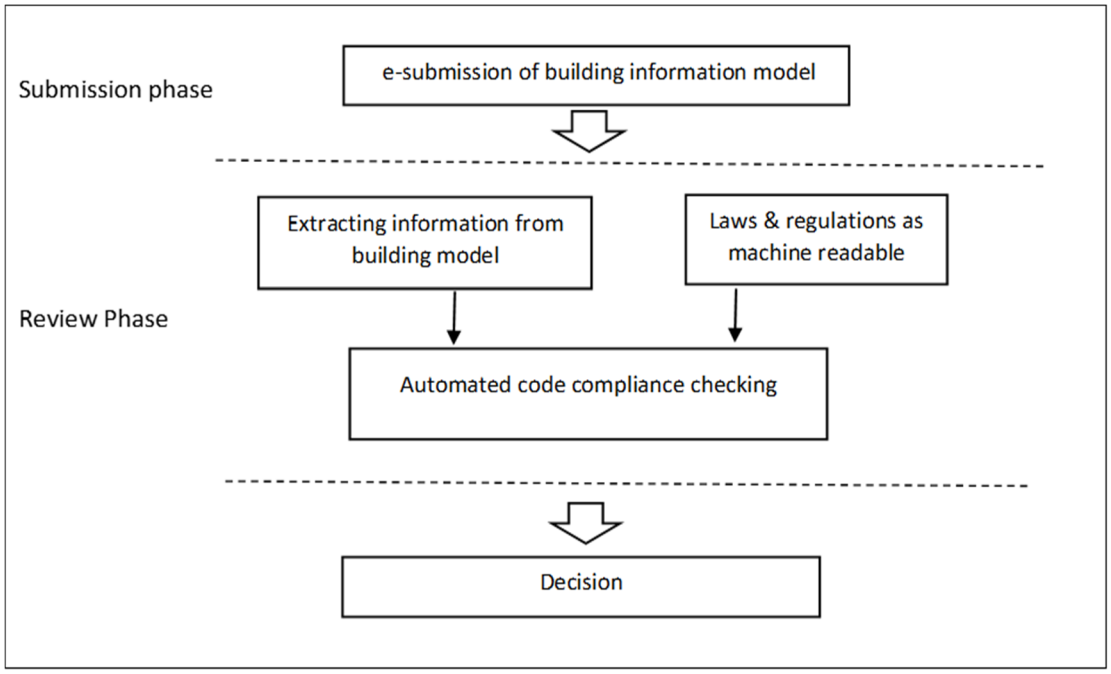

Figure 1. General conception of the BIM-based building permit process (adapted from Shahi et al. [4]).

Due to multiple potential advantages of BIM-based building permit processes over traditional procedures, various authors have recently made efforts to examine them. Guler and Yomralioglu [3] proposed a reformative framework focusing on the applications of digital building models, formulated in international standards, such as IFC, CityGML, etc., for issuing building permits in Turkey. Their proposed framework is also aimed at facilitating the process of property ownership through 3D registration. A study by Lee et al. [18] was focused on translating Korean building legislation into a machine-readable format through a rule-making method for its use in evaluating building permit requirements.

Park et al. [19] also focused on developing methods for translating laws and regulations for automated code compliance checking in Korea. Kim et al. [7] established a framework for a prototypal system called KBIM submission, which supports the submission of an IFC data model for the permit process. Choi and Kim [20] investigated an automated pre-checking system based on open BIM for the building administration process. Meanwhile, Narayanswamy et al. [21] presented a prototype for automated design checking of residential and small buildings based on BIM models for building permit issuance. Plazza et al. [22] investigated the potential applications of BIM implementation for building permits in public authorities.

Although digital solutions capable of accepting BIM models for building permit processes by regulatory authorities are not currently common, some public authorities and municipalities in different countries have either incorporated building information models into the permit process to some degree, or have undertaken pilot projects for the research and development of such systems. The CORENET e-Submission system of the Building and Construction Authority, Singapore is considered to be a pioneer of BIM e-submission for building permit applications. The CORENET e-Submission system is capable of accepting architectural, structural, mechanical, electrical, and plumbing (MEP) BIM models [23]. In Finland, based on the success of the KIRA-digi project, the building control department of Vantaa is also accepting BIM models in IFC format, and using Solibri Model Checker to perform checks [24]. Other countries, such as Norway, The Netherlands, Sweden, and Italy, also have projects supported by public authorities related to the use of BIM models for building permit processes [25].

2.2. Prevailing Research on Factors Affecting BIM Adoption

Adopting BIM in any organization is a challenge [26], as BIM is not just software, but also involves people, information, and process [27]. As a sociotechnical system, various factors affect BIM adoption, and the identification and analysis of these factors are essential, as the outcomes of BIM utilization are a function of the quality of its adoption process.

The review of the literature on BIM-based building permit processes in Section 2.1 shows that attention is mostly given to investigating potential applications of BIM for building permits, developing and testing prototypes, approaches for translating rules and regulations into machine-readable forms, and the development of different conceptual frameworks for BIM-based building permit processes. However, research focused on studying the factors that affect BIM adoption in public organization for building permits is scarce.

Though research specifically focused on BIM-based building permits is limited, many studies have been performed in numerous countries on the factors affecting the BIM adoption process in the AEC/FM industry generally. These include studies carried out in Australia [28], China [10], Finland [29], Norway [30], Singapore [31], South Korea [32], United Kingdom [33], and USA [34]. In an earlier study [35], a systematic review and analysis of existing research on factors affecting BIM adoption in AEC/FM was carried out, which resulted in the identification of various influencing factors categorized using the Technology–Organization–Environment framework as shown in Table 1.

Table 1. Factors affecting BIM adoption in the AEC/FM industry, adapted from ref. [35].

Factors Affecting BIM Adoption in AEC/FM Industry	
Technological factors	Complexity
	Relative advantage
	Compatibility
	Trialability
Organizational factors	Top management support
	Behavioural intention
	Training and learning
	Awareness
	Organizational culture
	Leadership
	Innovativeness
	Motivation
	Trust
Environmental factors	Client pressure
	Competitive pressure
	Partner pressure

3. Methodology

As factors influencing BIM adoption in public organizations for the building permit process have scarcely been examined, an exploratory research design was adopted. According to Fellows and Liu [36], the main feature of exploratory research is the exploration of knowledge about processes for which limited information is available. A single case study strategy was used in this research, as it offers deeper understanding, and details the existence of a particular phenomenon [37]. The single case study strategy has been employed in various BIM-related studies, for example, Bråthen and Moum [38], Gledson [39] and Shibeika and Harty [40]. A case study investigates and offers rich information about a contemporary phenomenon in its real-world context, using data collection techniques, such as interviews, questionnaires, observations, document analysis, and others [41]. Case studies are useful, as they provide a unique way of problem solving [42], and gather meaningful descriptions about real-life events [38]. The case used in this study is the adoption of BIM by the Tallinn City Government (TCG) for their building permit process.

Previous studies [10,28,31,32] on factors impacting BIM adoption in AEC/FM industry predominantly used quantitative approaches through questionnaire surveys. In this study, a qualitative approach through semi-structured interviews was used to gather data. Semi-structured interviews do not limit the interviewees to strictly follow interview protocols, and they allow for additional questioning as required for further explanation or clarification [43]. To fulfil the aim of this study (i.e., examining the factors affecting BIM adoption by public authorities for building permits), interview questions were designed as open-ended questions, which allowed interviewees to openly express their opinions. The general concept of interview questions was derived from previous studies on BIM adoption in AEC/FM industry; however, questions were not directly based on the factors observed in the literature review in order to avoid restricting or leading the interviewees' responses. Rather, they were asked broad questions as follows:

- Describe the difficulties/challenges in adopting a BIM-based process for building permits, and how these challenges were dealt with/solved.
- Describe the factors which enabled the adoption of a BIM-based process for building permits.

The interviewees were selected through purposive sampling following desk-based research about their background information and involvement in the case, which allowed the selection of interviewees focusing on their particular experiences and perceptions. The interviewees were stakeholders from TCG, the Ministry of Economic Affairs and Communications (MoEAC), and from a software development organization. Initially, 15 interview invitations were sent out; however, only 7 people accepted the invitations and were subsequently interviewed. According to Farrell [44], the number of interviewees required for robust results is not a definite number; rather, it depends on the context and the research objective. Wilmot [45] suggests that, for a purposive, non-random sample, the selection criteria of interviewees is more important than the number of interviews. Considerable efforts were made to maximize the number of interviews; however, seven interviews were considered sufficient to achieve the aim of this research. This is also in line with the suggestions that the point of data saturation and establishing meaningful themes can be achieved with a minimum of six interviews [46,47]. The interviewee's profiles and years of experience in their occupations are shown in Table 2.

Table 2. Profile of interviewees.

#	Interviewee Code	Role in the Organizations	Experience
1	Interviewee 1	Head of Department	16 years
2	Interviewee 2	Analyst	5 years
3	Interviewee 3	BIM Manager	8 years
4	Interviewee 4	CEO	23 years
5	Interviewee 5	BIM Manager	7 years
6	Interviewee 6	Head of Division	28 years
7	Interviewee 7	Analyst	12 years

The interview invitations included information regarding the aim of the study, and all participants were assured that their anonymity would be maintained. The interviewees were given the option of face-to-face or online interviews, but all the interviews were carried out using the online platforms Skype, Microsoft Teams, and Google Meet. To increase the reliability of the collected data, and minimize errors, all interviews were audio recorded with the consent of every participant. Thematic analysis of the gathered data was carried out following the guidelines by Braun and Clarke [48]:

- Familiarization with the data: transcribing the interview data, reading multiple times, and noting initial ideas.
- Making initial codes: systematically selecting important and relevant text from the entire data set.
- Searching for themes: gathering codes into potential themes.
- Reviewing themes for refinement.
- Defining and naming themes.
- Reporting the results of thematic analysis.

The data gathered from seven interviews were transcribed manually. A thematic analysis of the transcribed data was carried out using NVivo software to identify factors affecting BIM adoption for the building permit process. In the thematic analysis of the gathered data, the transcripts were first thoroughly read to get familiar with them. The important phrases in the text were highlighted, and relevant or matched phrases were coded to identify themes related to the research aim. Figure 2 illustrates the methodological flow chart of the study.

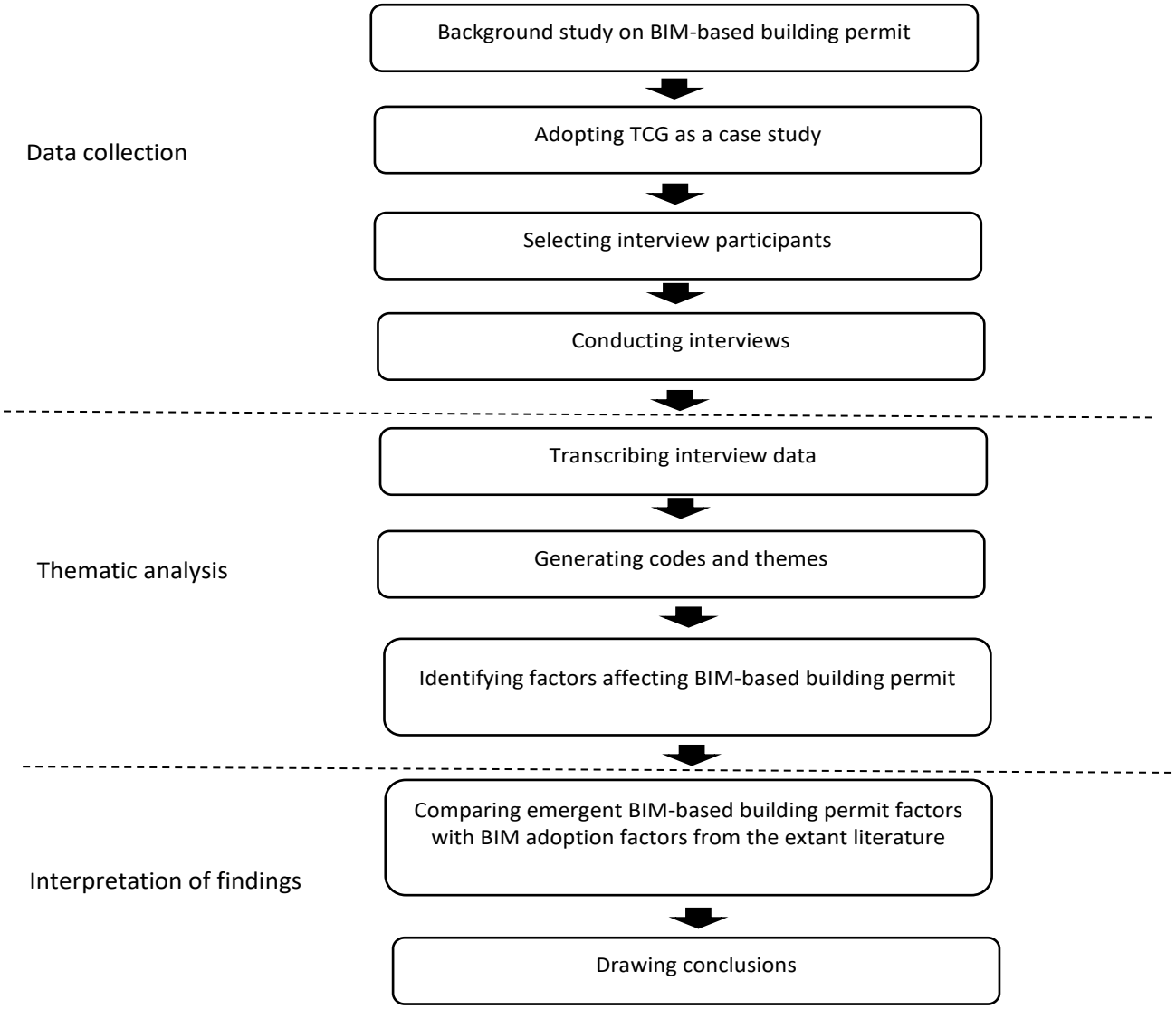

Figure 2. Methodological flow chart.

4. Case Study

The case studied here is the BIM-based building permit process of TCG. The planning department of TCG is responsible for issuing building permits, usage permits, and demolition permits. Before 2016, the building permit process was paper-based, and applications were submitted physically along with 2D drawings and other files for officials in the planning department to manually review. This was very time consuming and inefficient. From 2016, TCG has handled building permits through an online platform, the "Register of Buildings", which is managed by the Ministry of Economic Affairs and Communications (MoEAC), as the construction sector falls under the remit of the MoEAC. In the existing building permit process, the applicant submits digital 2D drawings and other pdf documents through the "Register of Buildings" platform electronically. These are then manually reviewed by city planning officials for compliance with codes, laws, and regulations. To make the building permit process more efficient, cost-saving, free of human errors, and transparent, the project "BIM-based process for building permits in Estonia" was initiated under a new e-construction platform vision in 2018. The BIM-based building permit process in the TCG project also belongs within this program. It is currently ongoing, and the roadmap for the BIM-based building permit process is shown in Figure 3.

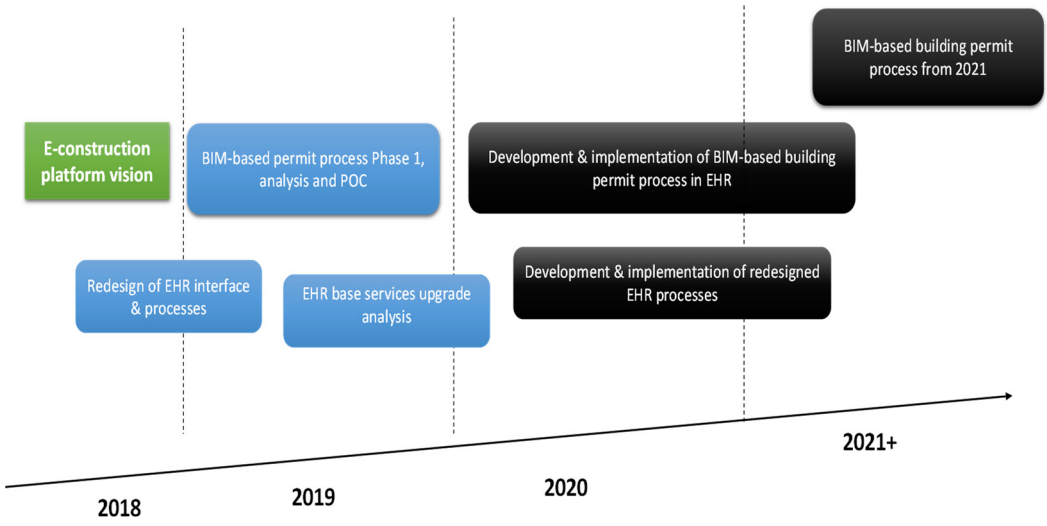

Figure 3. Roadmap for the BIM-based building permit process (source: Estonian Ministry of Economic Affairs and Communication).

The project is led by the MoEAC, as they "own" the Register of Buildings, which is used by all municipalities in Estonia for processing building permits. Thus, it is noteworthy to mention that the BIM-based building permit process will not be limited to TCG, but is also intended for all municipalities. However, TCG is the biggest municipality in the country, with high levels of construction activities, and it manages the most complex building permits. In 2020, the city planning department of TCG issued approximately 1149 building permits. TCG is the main partner with MoEAC in proof of concept, pilot projects, and training regarding the BIM-based building permit process. Hence, the BIM-based building permit process in TCG is considered as a case study in this paper. The chronological transition of the building permit process in TCG is shown in Figure 4.

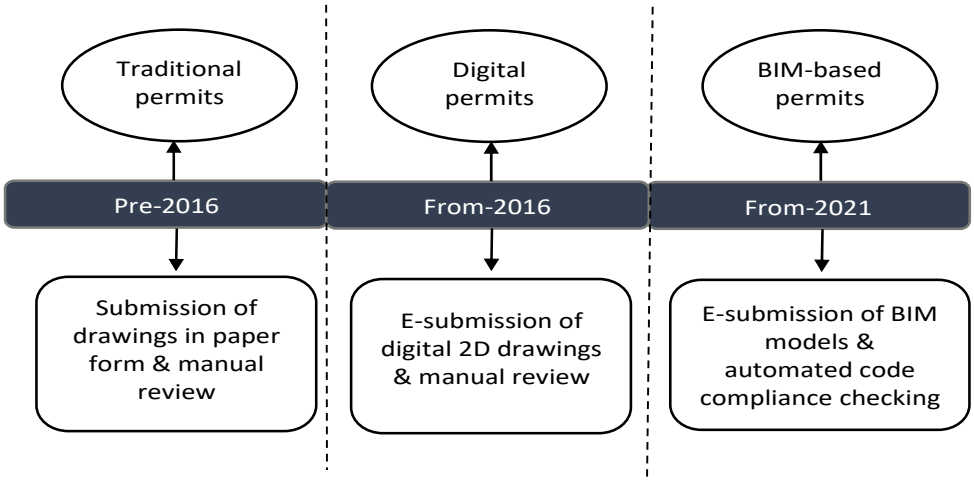

Figure 4. Building permit process transitions in the Tallinn City Government (TCG).

A proof of concept for the BIM-based building permit was developed by MoEAC with a private software firm. The proof of concept was intended to demonstrate the function of an automated BIM validation check. In the BIM-based building permit process, depending on the type of permit applied for, the applicant will upload a building information model in IFC format via the Register of Buildings platform. In the case of an invalid IFC dataset, the applicant will be notified to resubmit the BIM data in a valid format. The uploaded BIM data set will be saved to the server. The applicant can perform predefined checks depending on the type of permit to know in advance if the design meets the requirements,

and then submit the application. The planning department receives the application, and automated BIM model checks are carried out. Based on the results, an official from the planning department then decides if the building permit application is to be approved or rejected. The workflow for the proof of concept is shown in Figure 5.

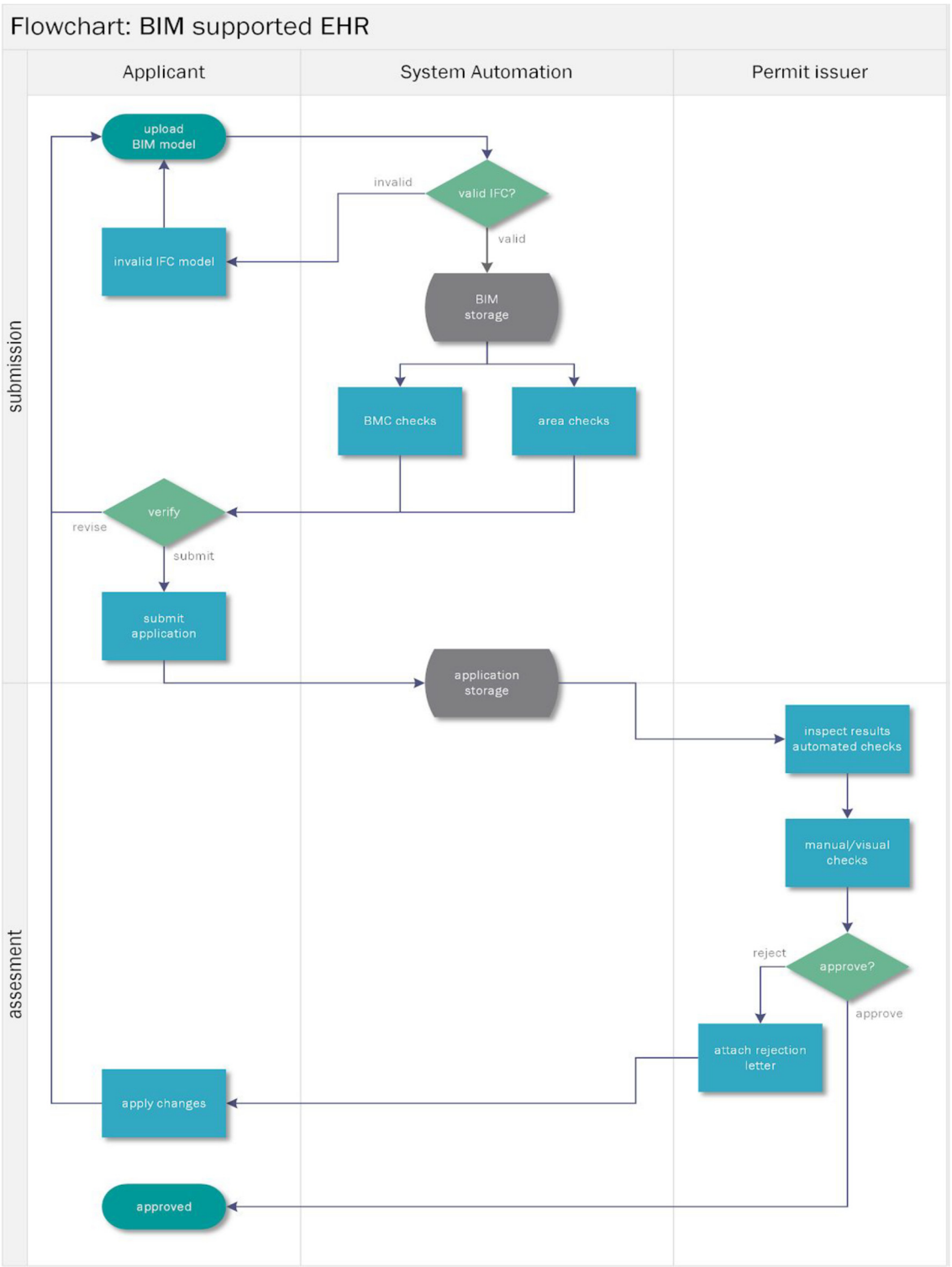

Figure 5. Proof of concept flowchart (source: Estonian Ministry of Economic Affairs and Communication (MoEAC), and Future Insight Group [49]).

The detailed BIM adoption process by the Tallinn City Government was analyzed in our initial study [35]. In this current study, the focus is to investigate the factors influencing BIM adoption for building permits.

5. Findings

The factors affecting adoption of a BIM-based building permit process were identified from the themes emerging in the data analysis related to the research aim. The prevalent responses from the interviewees in relation to emergent themes are summarized in Table 3.

Table 3. Summary of prevalent responses from thematic analysis.

Themes	Nodes from Interviews	Number of Interviewees Referencing Nodes
Complexity (in both development and use) of BIM-based building permit systems	BIM-based building permit process is something new and different from BIM adoption in AEC organizations	3
	Translation of rules and regulations into machine-readable is a difficult task	2
	Little experience of employees in using BIM	7
Relative advantages/disadvantages of BIM for building permits	Stakeholders' perceptions of potential benefits act as enablers	6
The existing building permit system	Current e-permit system acts as motivation for further digitalization	3
Management support for BIM-based building permit process	Active involvement of management	4
Organizational culture	No resistance towards BIM adoption	5
	Learning new system might be difficult for some employees	4
BIM awareness	Aware of BIM potential benefits	5
Training and learning	Training and learning are key for BIM-based building permit process	3
Available expertise on a BIM-based process for building permit process	Very few experts	6
External pressure	No direct external pressure towards BIM adoption	3
	Existing few BIM-based permit processes in other countries acts as motivation	2
Legal context	Currently no legislation for BIM-based process for building permits	3

5.1. Factors Affecting BIM Adoption for Building Permit Process

5.1.1. Complexity (In Both Development and Use) of BIM-Based Building Permit Systems

Five of the interviewees mentioned that one of the main factors affecting the BIM-based building permit process is the technical difficulty faced in developing the BIM-based building permit system. According to the interviewees, the BIM-based building permit process is something very new, and a desktop study was performed before developing proof of concept to look around the world for such systems to get ideas. Although a few municipalities use a BIM-based process for building permits up to some level, these were found too complex from the users' point of view. However, in the case of TCG, the focus was to keep the BIM-based building permit system user friendly, as mentioned by Interviewee 1:

> *. . . The key for the BIM-based building permit process is that it has to be really simple, because on one side there are for example design firms having professionals dealing with BIM in their everyday work already but on other side in municipalities majority of the people dealing with building permit never used BIM as they just deal with 2D drawings.*

For developing a BIM-based building permit system capable of automated code compliance checking, the translation of the contents of codes and guidelines to a machine-readable language is one of the core tasks. On difficulties related to the translation of rules and regulations to a machine-readable form, Interviewee 4 mentioned that:

> *. . . To make the auto checks the rules and regulations should be in machine-readable, some rules and regulations are not clear, it contains quite vague statements and occasional use of subjective expressions, making it difficult to convert them into machine-readable through programming.*

The complexity is not limited to the development phase, but also for the end users. In the municipality, there are people who have been working for a long time, and the majority are in the older age groups accustomed to the existing building permit system, so using a new system could be difficult for them, as mentioned by Interviewee 2:

> *. . . . Learning the new system might be quite difficult and it cannot be developed as simple as like the current building registry, which is also not an easy thing to learn, when new people come, it actually takes a while to learn the current system.*

The accuracy of auto checks results depends on the correctness and availability of information in the submitted BIM model. Although many architectural firms are already using BIM, when it comes to a BIM-based building permit process, the models have to be presented in a highly standardized way, and must be saved in the required format with consequent interoperability issues. Currently, the MoEAC is developing BIM standards, initially for public clients, but these will later provide a form of general Estonian BIM standard. Interviewee 1 highlights this as:

> *. . . . Another challenge is how to make sure that the BIM models that are uploaded to the system correspond to standards because the model needs to have certain elements and certain properties classified according to the standards.*

5.1.2. Relative Advantages/Disadvantages of BIM for Building Permits

A BIM-based building permit process potentially offers various advantages, such as high efficiency, cost savings, time savings, high accuracy, and a transparent process. In the opinion of most of the interview participants, these potential advantages of BIM for building permits played a vital role in the decision to adopt it. According to the interviewees, the already established BIM applications in the AEC/FM industry in general, and the successful experiments on BIM-based model checking solutions from other countries, such as Norway, Netherlands, and Finland, were among the reasons to start efforts for leveraging BIM in the Estonian Register of Buildings for building permits. A selection of comments related to the relative advantages of a BIM-based building permit process by Interviewee 3 and Interviewee 1 are:

> *. . . . The developed BIM-based building permit system gives the possibility to improve functionalities of municipalities particularity TCG, which deals with high number of permit applications comprised of complex buildings.*

> *. . . . The BIM-based building permit process will not be limited to TCG, other municipalities in Estonia will also use it, so probably we are the first or among the first countries in the world implementing BIM for building permit at a national level.*

Interviewees argued that the Estonian construction sector productivity is currently low, and that low digitalization of the construction sector is one of the main reasons. The Estonian government aims to increase it by a factor of three by 2030 [50], partly through digitalization, as stated by Interviewee 6:

. . . . To increase construction productivity, e-construction platform vision has been started, and the BIM-based process for building permits is part of that bigger ambition.

5.1.3. The Existing Building Permit System

TCG has been using a basic e-permit system from 2016, so an element of digitalization on a small scale is already there. According to interviewees, the existing building permit system acted as an enabler towards a BIM-based building permit, as mentioned by Interviewee 1:

. . . .. We are somehow in good position as we have a digital building permit process already, which is mandatory, based on digital files such as pdf and signing the files through digital ID, so there is not a sudden shift from complete paper based to BIM-based built permit process.

Interviewee 6 had a similar perception that if the transition was from a paper-based building permit procedure to a BIM-based permit process, TCG would have faced a lot more challenges both in terms of technology and people.

5.1.4. Management Support for a BIM-Based Building Permit Process

According to the interviewees, one of the most important enablers in adopting BIM was the support from top management. Management support acts as a change agent in the BIM adoption process, as it also effects other drivers for BIM adoption i.e., providing resources, providing adequate BIM education, BIM awareness, and the selection of appropriate tools. Some of the interviews were carried out with top officials, and their commitment and support for BIM-based building permits was quite obvious. Comments by Interviewee 3 and Interviewee 5 highlighting management support are:

. . . there is huge role in transferring towards a BIM-based building permit process from the Ministry of Economic Affairs and Communication as well.

. . . Management is motivating the employees towards BIM by explaining its benefits and trying to help them through organizing different training courses.

5.1.5. Organizational Culture

Organizational culture reflects the attitudes, values, norms, and behaviors of the organization members. When it comes to organizational culture regarding innovation adoption, some people show more interest based on its perceived usefulness and perceived ease of use compared to others. The participants of the interviews described the attitudes of people handling building permits as very positive towards BIM. A comment by Interviewee 3 reflecting end users' attitude towards a BIM-based building permit process is:

. . . The people working at TCG are welcoming BIM-based process for building permit. So far, I have not heard a single time if someone is saying, well this BIM-based building permit will be a waste of time or it will give us a lot of extra work, they are expecting it quite positively.

Interviewee 2 highlighted the existing digital permit system's role in the positive attitudes of TCG employees towards BIM as:

. . . the current digital permit system saves time compared to traditional paper-based building permit, based on that TCG employees have already seen benefits of using technological tools, and now the BIM-based building permit capable of automatic checks will make the overall process highly efficient.

Even though, in general, the organizational culture is positive towards BIM adoption, Interviewee 4 highted that:

...Some people are innovative so they will welcome such processes, while others accustomed with the already existing system might not be very enthusiastic, however, arranging training programmes is key to such issues.

5.1.6. BIM Awareness

Regarding familiarity of municipality employees with BIM utilization for building permits, Interviewee 1 commented that:

> *. . . BIM-based building permit process is different from BIM use in other organizations for example, design firms as they have professionals using BIM as a tool for their work but people working in the municipalities checking building permits, majority of them have not used BIM because it was always 2D drawings required for building permit.*

Interviewee 3 mentioned that, in the beginning, basic BIM training was given to TCG employees to create BIM awareness, and highlight its potential applications in the building permit process.

5.1.7. Training and Learning for BIM-Based Building Permit Process

BIM, as an emerging technology, requires specialized learning and training for its utilization. There were comments regarding training and learning in almost all interviews, which shows their importance for BIM-based building permit processes. Regarding the significance of BIM training, Interviewee 5 stated that:

> *. . . . Once we have the knowledge and experience of BIM, then using BIM for building permits is not complex. However, it is also understandable that analysts at municipality are accustomed to existing system, so transfer to a BIM-based building permit process would require time for them.*

According to Interviewee 3, three types of BIM training have been provided so far to TCG employees working in the departments related to building permits. First, was basic BIM training: its purpose was to create BIM awareness, and explain its applications. The basic training was followed by advanced training. There was also BIM model checking training using Solibri model checker software. Solibri model checker was selected as, during that time, the system which is to be used by TCG was in the proof-of-concept phase, and the purpose of the Solibri model checker training was to demonstrate automated checking and the efficiency of such systems.

The interview participants highlighted that, for training and learning, the focus is not only on the TCG employees who are handling building permits, but also on training the applicants. A comment by Interviewee 1 relating to this is:

> *. . . In regard to requirements for BIM model submission, we do not want to set requirements something entirely new as there are companies already using BIM, so our base line is the already existing best practise for BIM models creation, further there will be templates for BIM submission, guidelines for BIM submission, and tutorial videos to assist the applicants.*

Though training and learning have highly positive impacts on BIM implementation, one of the issues with training and learning highlighted by Interviewee 2 was the age factor:

> *. . . .. The municipality is shattered in many departments and a lot of employees are physically old, already used to with the existing system, might not be interested to learn new technological things.*

5.1.8. Lack of Experts on BIM-Based Building Permit Process

One of the challenges highlighted by the interviewees is that currently, in the municipalities, the number of people with BIM expertise or knowledge is quite small. Interviewees suggested that the existing building permit system could be a reason for this, as it is based on 2D drawings and manual checking, as stated by Interviewee 2:

> *...Regarding the BIM tools knowledge, for example in my department very few people are familiar with Solibri model check concept.*

The same interviewee mentioned that establishing new positions, such as BIM coordinator, and providing BIM knowledge to the existing employees are key to dealing with this issue.

5.1.9. External Pressure

External pressure, such as government mandate, client pressure, and competitive pressure, influences BIM adoption decisions. In the case of TCG, there were no such direct pressures for BIM adoption; however, interviewees highlighted the motivation coming from some external sources. Interviewee 3 and Interviewee 1 comments related to this are:

> *. . . there are already many companies using BIM in their work process but when it comes to building permit, they require to submit 2D drawing and other information in pdf file costing them extra work, the overall process will be more productive if TCG starts to accept BIM datasets for building permit.*

> *...Earlier experiments and examples of BIM-based model checking solutions in Finland, Norway, Netherland and CORENET in Singapore indicated that a BIM-based building permit can be faster and cheaper than manual procedures.*

5.1.10. Legal Context

There are always essential laws and regulations regarding building permit procedures. Though the BIM-based building permit is in the implementation phase, some possible legal obstacles were noted by Interviewee 1:

> *...There might be some legal questions as well but currently we are not making it mandatory, but as we go issues might occur and we have to solve them.*

Interviewee 5 also mentioned that:

> *...the current law is not saying anything about BIM-based building permit process, but we have to focus on that side as well.*

6. Discussion

The analysis of the interview data indicated the stakeholders' perceptions regarding factors influencing BIM adoption for building permits. In total, ten factors were identified from the analysis of the interview data. Using the Technology–Organization–Environment framework [51], factors from the findings are categorized into three groups: technology, organization, and environmental factors, as shown in Table 4.

Table 4. Factors affecting BIM adoption for the building permit process.

Factors Affecting BIM Adoption for the Building Permit Process	
Technological factors	Complexity in developing and using BIM-based building permit system
	Relative advantages/disadvantages of BIM for building permits
	Existing building permit system
Organizational factors	Management support for BIM-based building permit process
	Organizational culture
	BIM awareness
	Training and learning for BIM-based building permit process
	Lack of experts on BIM-based building permit process
Environmental factors	External pressure
	Legal Context

The findings reflect that adopting BIM in municipalities is different and relatively challenging in terms of technology (software) and users' experiences compared to BIM

adoption in general AEC/FM organizations. In the technical context, in the case of AEC/FM organizations, the BIM tools are already there. For example, if an architecture firm decides to adopt BIM, multiple BIM software applications, such as Autodesk Revit, ArchiCAD, etc., are available to create model-based designs. This can also be observed in previous studies investigating factors affecting BIM adoption in the AEC/FM industry, e.g., Ma et al. [10] and Qin et al. [11], which highlight that the lack of BIM tools is not a major barrier or a commonly reported challenge. However, when municipalities decide to adopt BIM, the system which is capable of automatically checking submitted BIM models against set rules and regulations needs to be developed, as each country has their own rules and regulations. Sometimes, the rules and regulations also vary from municipality to municipality within the same country. In the current case study, initial challenges observed relate to developing their own system, which should be web-based, have a simple user interface, support open standards, and be based on the Estonian BIM standard. The issue of the lack of suitable software is also associated with GeoBIM integration for building permits, as highlighted in the study of Noardo et al. [14].

The high cost associated with software is often a barrier to BIM adoption [52]; however, the current study did not capture any financial difficulty faced by TCG towards adopting a BIM-based building permit process. The main reason for this appears to be that the technology for the BIM-based building permit process is provided by MoEAC, indicating that government support can play a key role in enabling a BIM-based building permit process in municipalities.

Previous studies on factors affecting BIM adoption reported complexity relating to the difficulty in using BIM tools as one of the main factors, for example, in the studies by Ahuja [53], and Gledson and Greenwood [33]. This can also be observed in the findings of the current case study. However, in order to minimize the complexity of this BIM-based building permit system, the developed proof of concept is web-based, with an easy-to-use interface, and is capable of automated checks according to respondents.

The findings of this study show that one of the most important enablers for adopting BIM for building permits is stakeholders' perceptions of the potential advantages associated with BIM technology. Relative advantages not only affect the decisions of top management to adopt BIM, but also act as motivators for the employees of the organization. As reported in the literature, for example, by Hong et al. [28], benefits associated with the implementation of BIM are a significant motivational factor.

The already existing norms and practices were found vital for successful BIM implementation, and the participants indicated that TCG is in a relatively good position due to the current capacity of the Register of Buildings to accept digital files. The role of the existing basic e-permit system (Level 1 in the framework of Shahi et al. [4]) in TCG's efforts towards a BIM-based building permit process shows that a step-by-step approach can be adopted, particularly in the municipalities of developing countries that may face greater financial difficulties.

A top-down approach was observed in the current case study: a decision from top management to adopt BIM, and then their direct involvement in the development phase of the system, and training of the employees. This shows the significance of top management support as a major driver in adopting BIM, which has also been highlighted in previous studies [31,53].

Challenges related to the lack of BIM experts were observed: for example, the interview participants stated that, currently, only a very small number of people working in TCG have a background of using BIM. Creating new positions related to BIM in TCG, and, in addition, training and learning programs are already underway to address this issue. It was observed that the purpose of training courses was not only related to skills development, but also created BIM awareness, and changed cultural resistance to BIM. This aligns with the studies of Liao and Teo [31] and Ma et al. [10] that emphasize the role of training and learning for successful BIM implementation.

As noted earlier, BIM adoption in municipalities differs compared to other organizations, and this is evident in the environmental factors that influence BIM adoption. In AEC/FM organizations, pressure from clients can play a vital role in decisions to adopt BIM. In addition, as it has become evident that BIM offers a better way of working, many large companies have already adopted BIM, and this forces others (competitors, as well as subcontracting and supplier organizations) to adopt BIM in order to maintain their market positions. In the case of TCG, there are no such external competitors imposing significant pressure to adopt a BIM-based building permit process. Though the interviewees did not reveal much information regarding legal obstacles, according to Shahi et al. [4], attention should be given to legal concerns, for example, in relation to the confidentiality and security of designs.

This research and other studies on BIM-based building permit processes show that BIM implementation is occurring in government agencies and municipalities, but BIM adoption by municipalities is particularly difficult, and comes with many challenges. However, as shown by the examples of successful BIM-based building permit processes by the Building and Construction Authority in Singapore; City of Vantaa, Finland; and various experiments in Nordic countries, municipalities facing inefficiencies in building permits should consider the potential benefits of a BIM-based permit process.

In comparison with previous studies which have mainly focused on prototypes/solutions for BIM-based building permit processes, translations of rules and regulations into machine-readable formats, etc., thus providing a technical perspective, the main contribution of this paper lies in its investigation of the BIM-based building permit process from an organizational perspective. The study reveals that adopting BIM for the building permit process in municipalities or public regulatory organizations is challenging, but management support, benefits associated with the BIM-based building permit system, early involvement of municipality employees through training programs, and BIM awareness can all act as catalysts towards successful BIM-based building permit process implementation. The single case study, qualitative approach employed has enabled the in-depth understanding of the phenomenon under investigation (BIM adoption for building permit processing) through the insights of interviewees who have considered this single (TCG) instantiation of the phenomenon from their own (unique) standpoints. This has unveiled a rich, multifaceted view of the organizational context, which is valuable in furthering our understanding in this relatively new area of research.

However, since this research is based on a single case study, which, on the one hand, allows greater depth than a comparative analysis of multiple case studies that would need to account for the (organizational) differences between cases, it may also limit the generalizability of its findings to other municipalities and countries. In addition, the number of interviews (7) was relatively low. Though a larger number of interviewees was initially anticipated, and may have revealed additional, specific insights, the authors are confident that the findings, in terms of nodes, themes, and factors, are robust and are unlikely to have been significantly affected by further interviews.

Whereas other existing studies on BIM adoption factors in the AEC/FM industry have mostly employed quantitative methods, this investigation has used a qualitative approach to enable an understanding of stakeholders' perceptions of the context of TCG's BIM-based process for building permits, and led to the derivation of a list of factors that affect it. Such an exploratory study reveals little about the relative importance or statistical analysis of each factor, and future studies will investigate this using quantitative or mixed method approaches to reveal more detailed information. Moreover, future studies are encouraged to help mitigate the challenges associated with BIM-based building permit processes, for example, through multiple criteria assessments, and the development of decision support systems for BIM-based building permit processes. In addition, the findings of this study can be used in future research with larger sample sizes focused on determining the critical success factors and strategies for effective implementation of BIM-based building permit procedures.

7. Conclusions

Recently, BIM has gained growing interest from public organizations, such as municipalities, for integrating BIM into their building permit procedures due to the potential benefits, i.e., faster, cheaper, more transparent, and easier tracking than manual processing. However, the implementation of a BIM-based building permit process is challenging due to various factors. This paper identified factors affecting BIM adoption for building permits through a case study. The responses from seven interviewees resulted in the identification of 10 factors affecting BIM adoption for building permit processes:

- Complexity (in both development and use) of BIM-based building permit systems;
- Relative advantages/disadvantages of BIM for building permits;
- The existing building permit system;
- Management support for a BIM-based building permit process;
- Organizational culture;
- BIM awareness;
- Training and learning;
- Available expertise on BIM-based building permit processes;
- External pressure;
- Legal context.

Some of the identified factors were found to be similar to factors affecting BIM adoption (generally) in the AEC/FM industry, whereas others were specific to the building permit process. Using the Technology–Environment–Organization framework, the identified factors were categorized into three groups. Factors such as the relative advantage of BIM, BIM training, and management support were found to be enablers of a BIM-based building permit process. Particular challenges were revealed in terms of the technical development of a BIM-based building permit process. The study found that special attention should be given to the development phase of systems for BIM-based building permit processes in order to decrease the effects of complexity of technology on end users. The findings of this study are expected to contribute to the small, but growing, body of research on BIM-based processing of building permits. The results are important for public authorities' understanding of both the enablers and challenges of BIM-based building permit processes, and have practical implications for professionals in public authorities in particular, and also in the AEC/FM industry in general, to guide their steps in adopting BIM.

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