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An Empirical Analysis of Barriers to Building Information Modelling (BIM) Implementation in Wood Construction Projects: Evidence from the Swedish Context

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Abstract: Building information modelling is gradually being recognised by the architecture, engineering, construction, and operation industry as a valuable opportunity to increase the efficiency of the built environment. Focusing on the wood construction industry, BIM is becoming a necessity; this is due to its high level of prefabrication and complex digital procedures using wood sawing machines and sophisticated cuttings. However, the full implementation of BIM is still far from reality. The main objective of this paper is to explore the barriers affecting BIM implementation in the Swedish construction industry. An extensive literature review was conducted to extract barriers hindering the implementation of BIM in the construction industry. Secondly, barriers to the implementation of BIM in the wood construction industry in Sweden were extracted using the grounded theory methodology to analyse expert input on the phenomenon of low BIM implementation in the wood construction industry in Sweden. Thirty-four barriers were identified. The analysis of this study also led to the development of a conceptual model that recommended solutions to overcome the barriers identified to help maximise BIM implementation within the wood construction industry. Identifying the main barriers affecting BIM implementation is essential to guide organisational decisions and drive policy, particularly for governments that are considering articulating regulations to expand BIM implementation.

Keywords: building information modelling (BIM); wood construction; grounded theory

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1. Introduction

The adoption of building information modelling (BIM) is growing at an exponential rate [1]. The global market for BIM was valued at USD 5.4 billion in 2020, and it is expected to grow to USD 10.7 billion by 2026 [2]. BIM is gradually being recognised by the architecture, engineering, construction, and operation (AECO) industry as a valuable opportunity to increase the efficiency of the built environment [2]. The adoption of BIM in different areas provides promising opportunities; for example, in the scope of facility management, BIM can reduce the operation and maintenance costs by providing a unified data source for accurate information about the facility [1]; BIM can reduce building energy consumption and support energy analysis [3]; BIM can facilitate sustainability and Life Cycle Assessment (LCA) [4–6]; and BIM, with its visualisation tools and 4D and 5D capabilities, can support scheduling and budgeting activities [7,8], increase quality [9], and reduce occupational risks [10].

One of the primary factors significantly driving market expansion is the rapidly expanding construction sector, substantial technology improvements, and government initiatives to mandate BIM implementation [4,5]. BIM is hailed as the answer to open communication, cost cutting, and energy efficiency. BIM is making its way from trendy ephemera to national legislation in many countries, such as the UK. In fact, the UK government has mandated the utilisation of BIM in every government construction project [6]. Europe is another key player in the global BIM movement. There is a clear push to achieve a fairer understanding of the practice. For example, the French government established a construction research and development initiative to support the establishment of BIM standards in infrastructure development [7]. As a result, the French BIM roadmap was established, and the country mandated BIM. Another European country that has adopted a national BIM strategy is Germany. This was accomplished by standardising methods and advocating for BIM to be made a requirement in public infrastructure projects [8]. For more than a decade, Nordic countries have been implementing BIM in both the public and private sectors [11]. The requirement originates from initiatives in which there is a lack of clear communication across construction project phases [2,10].

As for Sweden, in the absence of official government mandates for BIM, the shift towards implementing BIM in the Swedish construction industry is led by pioneers of the industry. The early steps towards BIM implementation were taken by representatives from several companies forming a BIM alliance or BIM network [12]. In this network, the focus was to pave the way for BIM implementation in Sweden by addressing barriers and promoting the use of BIM. The shift towards BIM is ultimately receiving more attention; however, as in many other countries, old approaches are still practised, and the full potential of BIM is yet to be achieved [2,10,13], meaning there are still barriers preventing and delaying the full implementation of BIM.

Focusing on the wood construction industry, BIM is becoming a necessity; this is due to its high level of prefabrication and complex digital procedures using wood sawing machines and sophisticated cuttings [11,14]. Currently, 3D models for machine production are being used to some extent, and digitalisation and automation of prefabrication are constantly developing [14]. However, the full implementation of BIM is still far from reality [15,16]. The move towards BIM is evident in the wood construction industry in Sweden in general. Nevertheless, it is still not fully implemented, and the level of BIM implementation in the wood construction industry is considered lower than in some other developed countries [17,18]. This emphasises the necessity for identifying and understanding barriers that are hindering full BIM implementation and paving the way for solutions to overcome these barriers.

The main aim of this paper is to explore the barriers affecting BIM implementation in the Swedish construction industry. These barriers are identified as issues that are preventing a large segment of industry practitioners from shifting towards a BIM-enabled project environment or are hindering the full implementation of BIM in the optimum way to realise the potentials that BIM offers for the industry. This research focuses on the wood construction industry in Sweden, and as such, this research can guide the industry to generate more practical and effective BIM application strategies, thus increasing the level of BIM implementation in Sweden. To achieve this, firstly, an extensive systematic literature review was conducted to extract barriers hindering the implementation of BIM in the construction industry in general, considering the lack of literature focusing on BIM implementation in the wood construction industry. Secondly, barriers to the implementation of BIM in the wood construction industry in Sweden were extracted using the grounded theory (GT) methodology to analyse expert input on the phenomenon of low BIM implementation in the wood construction industry in Sweden. The barriers are summarised from both grounded theory and the literature review to identify the final main BIM implementation barriers. Based on the research findings and discussions, recommendations and proposals for supporting the implementation of BIM are proposed and discussed. This research offers a valuable starting point for further research to facilitate and increase the level of BIM implementation in the wood construction industry by scrutinizing the main barriers that are currently preventing the full implementation of BIM and highlighting proposed solutions to overcome these barriers.

The research is organised as follows. In Section 2, the systematic literature review is outlined to extract and understand the barriers that are hindering BIM implementation in the wood construction industry and highlight the research gaps in this area in addition to the research gaps and limitations, followed by Section 3, which illustrates the methodology used in this study, including the analytical framework, data collection and analysis, and grounded theory. The results and discussion in Section 4 illustrate and discuss the barriers identified from GT, complementing the literature review findings, with a focus on the wood construction industry, in addition to discussion of recommendations concerning possible application issues. Conclusions and opportunities for future research are offered in Section 5.

2. Literature Review

As technology has advanced in recent years, the use of BIM has proven to be an innovative, useful, and effective factor in the development of sustainable projects [19–21]. The benefits of BIM have been recognised, particularly in the processes of design, performance assessment, visualisation, management, and, more recently, the operations and maintenance of the project [22–24]. However, despite the continuous increase in the use of BIM, the anticipated gain from the investment has not yet been perceived [25,26]. Advocates of BIM claim that the proper implementation of BIM holds benefits and value that far surpass the initial cost of investment and that, to date, the envisioned implementation of BIM has not been achieved [27].

In recent years, several initiatives concerning BIM implementation have been launched in several countries [20]; similarly, numerous studies in the literature have sought to create suitable strategies for BIM implementation [28,29]. This ongoing and increasing interest from both academia and industry proves that the proper and full implementation of BIM is still far from reality, and barriers to full implementation still exist.

2.1. BIM Implementation Barriers

The literature review critically examined articles focusing on BIM implementation barriers, and some articles examined the BIM implementation barriers in a selected country or region. Research undertaken by Daneshvartarigh [27] and Rossi identified barriers to BIM implementation with a focus on the European region [27,30]. Similar studies have been conducted in Canada [31], the UK [32–34], New Zealand [35], Poland [36], and the Middle East [28,37,38].

Other studies tackled the BIM implementation barriers with a focus on a specific aspect. A study by Saltarén and Gutierrez-Bucheli [39] examined barriers that are affecting BIM implementation in public infrastructure projects [39], while other scholars identified barriers that are related to BIM implementation in facility management activities [6,29,40]. Some recent research focused on investigating barriers to integrating BIM in building sustainability assessment [6,41–44], BIM for smart building energy and efficiency [31], BIM for prefabricated construction [45–47], BIM in renovation processes [27], and BIM for industrialised building construction [48].

The utilisation of BIM for prefabrication and modular construction has also received attention in several studies, and barriers concerning this subject were examined in several studies [6,42,43].

The examination of previous literature revealed an obvious lack of studies focusing on identifying the level of BIM implementation in Sweden. Only one paper was found that investigates the current use, barriers, and driving forces of BIM implementation among mid-sized contractors. The authors concluded in their study that the main barriers are a lack of demand from clients and the absence of internal demand in companies [49]. Furthermore, the literature review conducted in this study revealed that there is a lack of interest in exploring BIM implementation barriers that are hindering the expansion of BIM implementation in the wood construction industry in general and in Sweden specifically. Few articles have studied BIM adoption in the wood construction industry. For example, [50] investigated BIM implementation barriers, strategies, and best practices in wood prefabrication for SMEs in Canada. One of the main barriers was related to the effort needed to create BIM software libraries and the programs required to exchange information between BIM models and production equipment.

Table 1 illustrates the BIM implementation barriers as perceived from examining and analysing the recent literature. The articles used for the purpose of extracting the barriers were selected based on refining criteria to ensure (1) recency: this research aimed to capture the current position of the construction industry, considering that the state of the art in research related to BIM is moving at a fast pace; (2) relevance: barriers were extracted from research focusing mainly on developed countries. As this research focuses on the Swedish construction industry, it is logical to consider barriers from similarly developed countries, as the level of income plays a major role in the country's capabilities to adopt the latest technologies and to encounter fewer difficulties compared to developing and low-income countries.

Table 1. Barriers to BIM implementation as identified from the literature.

	Barriers to BIM Implementation	Reference
1	Incompatibility of BIM with the existing methods of working	[51] France; [52] Europe; [28] Saudi Arabia; [32] UK
2	Interoperability issues and data exchange	[53] Germany; [37] Saudi Arabia; [33] UK; [54] UAE
3	Not realising the effectiveness and benefits of BIM	[49] France; [51] Germany; [21] Global; [35] New Zealand
4	Lack of BIM knowledge and skills	[31] UK; [49] France; [50] Europe
5	Cost-related barriers (software licences, hardware devices, etc.)	[51] Germany; [32] UK; [21] Global; [14]
6	Lack of guidelines	[48] UK; [27] Saudi Arabia; [54] UAE
7	Fragmented nature of BIM (information is not stored in one location)	[49] France; [50] Europe; [26] UK; [33] UAE
8	Lack of standards and regulations	[49] France; [55] Canada; [50] Global; [48] UK
9	Reluctance to change	[9] Germany; [27] Saudi Arabia; [21] Global
10	Limitations of available software	[48] UK; [50] Europe; [33] New Zealand
11	Gap between the theoretical principles and practical implementations	[9] Germany; [49] France; [27] Saudi Arabia
12	Size of business	[48] UK; [27] Saudi Arabia; [26] UK; [53] Canada
13	Lack of leadership	[49] France; [27] Saudi Arabia
14	Lack of training sources	[49] France; [27] Saudi Arabia; [14]
15	Contractual issues	[53] Canada; [48] UK; [33] New Zealand
16	Lack of interest	[50] France; [51] Germany
17	Lack of demand from clients	[50] France; [47] UK; [21] Global
18	Time-related issues	[49] France; [27] Saudi Arabia; [53] Canada; [33] UAE
19	The prevailing culture in the construction industry	[51] Germany; [50] Global; [53] Canada, [33] New Zealand
20	Gap between actors (maturity level)	[49] France; [27] Saudi Arabia; [32] Saudi Arabia
21	Lack of government mandates	[50] Global; [50] Europe; [27] Saudi Arabia

2.2. Research Gaps and Limitations

Previous literature has revealed that BIM is not fully utilised and adopted in the industry, despite the realisation of the potential and opportunities that BIM offers for construction projects [17,23,29,51]. The existing literature also revealed an obvious lack of studies focusing on identifying the level of BIM implementation in the wood construction industry in general and in Sweden in particular. Table 2 summarises selections of similar studies and highlights the gaps and limitations in the currently available literature.

Table 2. Relevant literature focus and limitation.

Author/Year	Research Focus	Research Method	Limitation
- Durdyev et al., (2022)	Barriers to the implementation of BIM for facility management (FM)	Qualitative interviews	The research focuses on BIM applications for FM only.
- Alwisy et al., (2018) - Abushwereb et al., (2019)	Automation of design for wood manufacturing using BIM, focusing on prefabrication.	Propositions only	The research focuses on modular residential buildings only and not on wood construction in general.
- Al-Saeed et al., (2019)	Utilisation of BIM digital objects (BDO) in manufacturing design and production	Conceptual framework	The research focuses on the manufacturing part of the supply chain; the barriers to BIM implementation were not investigated.
- Pham et al., (2021) - Girginkaya Akdag and Maqsood (2020) - Alashmori et al., (2020) - Adam et al., (2021)	The implementation of BIM in the AEC industry in New Zealand, Pakistan, Seychelles, and Malaysia	Qualitative interviews	The studies focused on a specific country and on the construction industry in general.
- Lindblad (2019)	The public client's strategy in BIM implementation	Case study analysis from Sweden	The research focuses specifically on the client role only.

In view of the limitations presented in Table 2 and considering the lack of research focusing on wood construction in particular, further research is needed, especially to address certain gaps: (1) to identify barriers that are limiting BIM implementation in the wood construction industry and (2) to identify solutions to overcome these barriers, which will influence the level of BIM implementation in the wood construction industry.

Accordingly, this research aimed to identify barriers that are hindering the full implementation of BIM in wood construction projects in Sweden by investigating the phenomenon of low BIM utilisation in the wood construction industry in Sweden. The research adopted the grounded theory methodology for the theoretical identification of the factors that are causing this phenomenon.

3. Research Methods

Technology adoption in general is affected by several factors and complex interactions between project stakeholders. The level of BIM implementation in construction firms is impacted by various barriers and difficulties, and since this research aimed to identify these barriers from experts and practitioners of the industry, adopting a qualitative theory-building methodology seemed adequate to systematically identify these barriers and interpret them [22]. Achieving this aim requires deep insights into the central phenomenon and the causal factors. Accordingly, the research adopted a qualitative approach, which started by gaining a holistic understanding of the most recent barriers to BIM implementation in developed countries by conducting a systematic literature review covering articles from the last four years (2019–2022) using the Scopus database.

Considering the lack of research available on the subject, this study did not have too many prior theoretical assumptions to learn from. Thus, it is essential to start with actual observations, summarise experiences from the original data, and then build the theory to identify barriers to BIM implementation in the wood construction industry. The grounded theory method is considered to be the most scientific qualitative research method [22]. Its primary goal as a qualitative research technique is to develop a theory based on empirical evidence. The foundation of the grounded theory approach is to continuously use the comparison principle throughout the theory-building process. Researchers must draw comparisons from the first set of data in order to trigger thought and fully and succinctly understand the key features of research phenomena. Data can be sorted using comparison to determine the relationships between different phenomena [56]. Hence, this topic is a great fit for the grounded theory method in exploratory research. A bottom-up method named grounded theory is used to develop a substantive theory. It includes examining fundamental ideas that capture the phenomena through a systematic data collection process and then building pertinent theories by connecting these ideas. However, the major advantage of grounded theory is not that it is empirical in nature but rather that it abstracts new concepts and ideas from empirical facts [17].

Grounded theory has been broadly used in construction management and engineering science domains, such as identifying project performance risks. Shi et al. (2022) adopted grounded theory in research to identify planning risks in prefabricated buildings [57]. Grounded theory was found to be suitable for engineering studies that adopt qualitative methods and investigate behaviours or traits in industries, such as safety performance precautions [58] and maintenance management [24].

3.1. Research Framework

The research commenced with a literature review to establish a strong foundation for this research and to direct the research towards bridging the research gaps in the current state of the art. The systematic literature review analysed related studies on the subject of BIM implementation barriers in the construction industry to extract those gaps and to formulate the research question that would later be the basis for the grounded theory methodology. The research framework utilises two methods of data collection: the first is the literature review, which uncovers the barriers to BIM implementation in the construction industry in general, and the second method is grounded theory, which is aimed at extracting new barrier factors that are specific to the wood construction industry in Sweden from expert interviews. This research then recaps the research findings and provides recommendations to stimulate the implementation of BIM in the wood construction industry in Sweden. Figure 1 illustrates the research framework.

3.2. Grounded Theory (GT)

Grounded theory qualitative research intends to investigate the complex set of factors associated with the central phenomenon and to describe participants' perspectives regarding these factors. In typical GT research, a main open question is identified, rather than an objective or a hypothesis [59]. Several sub-questions should follow the main open question. The questions and the setting of the data collection have an exploratory nature to allow factors to emerge and develop around the main phenomenon. This research investigated the phenomenon of the implementation of BIM in wood construction projects in Sweden, and the GT method was employed to answer the open research question, which is: What are the barriers hindering the full implementation of BIM in the wood construction industry? The research employed the qualitative method of open-ended semi-structured interviews to collect data from industry practitioners around the identified phenomenon.

3.3. Data Collection

Interviewing is the most commonly utilised data collection method in grounded theory [54,59]. The interviews are designed to build concepts and theory and to allow data to emerge spontaneously until the extracted facts are "grounded" in the analysis [59]. This research utilised semi-structured open-ended interviews following a qualitative research strategy [54]. This method was found to be suitable for collecting experts' perceptions surrounding the identified phenomenon. Semi-structured interviews with industry practitioners were conducted to identify the barriers to BIM implementation in the wood construction industry. The interviews led to a better understanding of the phenomena [54] and to gathering truths about the reality of BIM implementation [59].

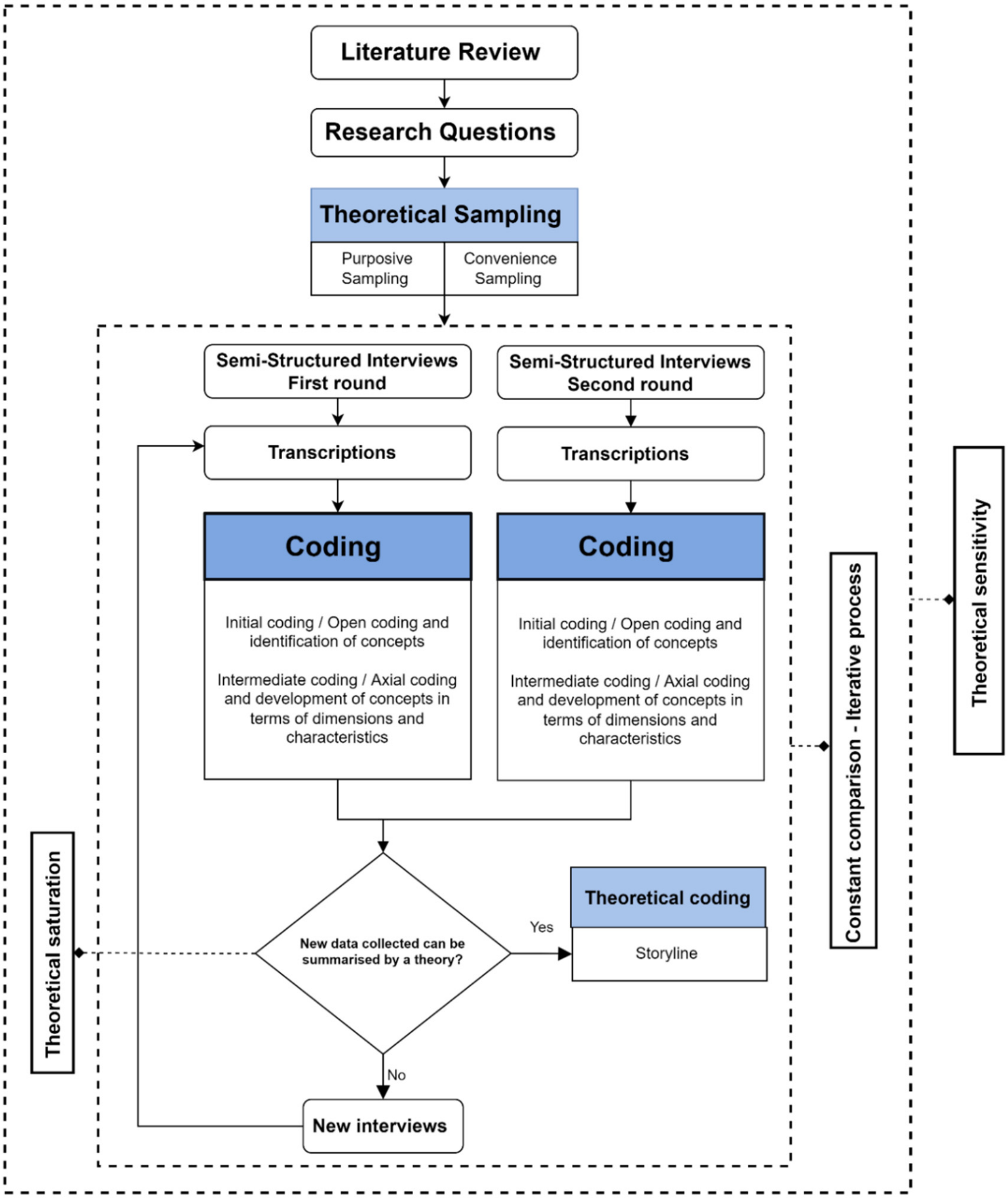

Figure 1. Research framework.

3.3.1. Participant Sampling

In GT, selecting participants is considered iterative [56]. The selection was initiated using theoretical sampling, meaning that the research was initiated by selecting a small group of participants loosely based on the initial research question. The loose selection of participants was conducted using purposive and convenience sampling methods [60]. Purposive sampling means that participants were selected based on predefined criteria. In this study, the criteria were defined to include participants from the Swedish construction industry and Swedish academics from construction-related fields.

Moreover, participants were selected from a database related to the Tillverka i trä (Wood Manufacturing) project, which is a project that involves several Swedish companies and organisations and focuses on wood industry innovation and is thus of strong relevance for this study [61]. The selection from a defined database is related to the convenience sampling method, where easy access to participants was needed (Bryman and Bell, 2015). The interviews were conducted in steps at the end of each group of interviews, the data were analysed, and the following group of interviews was determined. In GT, the data analysis and collection continue until any additional excerpts do not add to the coding categories, which is referred to as "theoretical saturation" [55].

3.3.2. First Round of Data Collection

Twelve interviews were conducted in the first stage with representatives from the industry and academia. The academic point of view was taken into consideration to assess the gap between research and industry practice in areas related to BIM implementation. The first round of interviews was transcribed, and the analysis was initiated using open coding. Open coding is the process of breaking the transcripts into excerpts. These excerpts are later continuously compared and contrasted in what is known as the "constant comparative method", which is the core of the grounded theory method [55]. Two repetitions of the process were conducted. The second round of interviews involved six participants, bringing the total number of interviews to eighteen. The descriptive data of participants are described in Table 3. The average duration of the interviews was 45 min, and the open-ended questions covered several themes focusing on the knowledge of BIM, the use of BIM within the company, and the difficulties and constraints that are preventing the implementation of BIM.

Table 3. Descriptive data of participants.

Background	Number of Participants	IDs	Role
Academic	2	11, 12	Lecturers in industrial engineering/construction management
Academic/Industry	3	1, 6, 14	Design consultants/senior lecturers/research development
Industry-Consultant	9	2, 3, 9, 10, 13, 15, 16, 17, 18	CAD/BIM consultants, innovation manager, architect, owner of structural design company, and architect/BIM strategist
Industry-Production	4	4, 5, 7, 8	Digitalisation manager, construction worker, project technician, and head of BIM
	Total: 18	Total: 18	

The participants were asked to provide answers to the core research question and describe the main difficulties or barriers that are preventing the full implementation of BIM in their working environments. Then, based on their answers, participants were presented with several open-ended sub-questions, such as: How do you see the level of BIM knowledge at your company? How sufficient are the current BIM libraries regarding wood objects? What are the data formats that are used to exchange information in your projects? These questions, among others, were used to urge the participants to tackle a broader view of the barriers within their own work environment.

3.4. Data Analysis

The data analysis was initiated by breaking the transcripts of the interviews into excerpts using open coding. NVivo software was used in this research to create "nodes" to encapsulate these groups of excerpts. Coding is essential for successfully implementing a grounded theory methodology [55], as coding provides the link between collecting the data and developing the evolving theory to derive explanations for the defined phenomenon.

This research followed the coding process offered by grounded theory, starting with the initial coding, followed by more focused coding, and finishing with theoretical coding [57].

At first, twelve interviews were conducted. The transcriptions were performed immediately after each interview to ensure the quality of the extracted data. The transcripts of the first batch of interviews were analysed, coded, and constantly compared. This act of comparison is an essential part of the grounded theory method and is known as the constant comparative method [57], where excerpts of raw data are sorted and organised into groups according to attributes in a structured way to formulate a new theory. The process of coding in GT is carried out in three successive stages, which are initial, axial, and theoretical coding. Figure 2 illustrates the coding map followed in the data analysis.

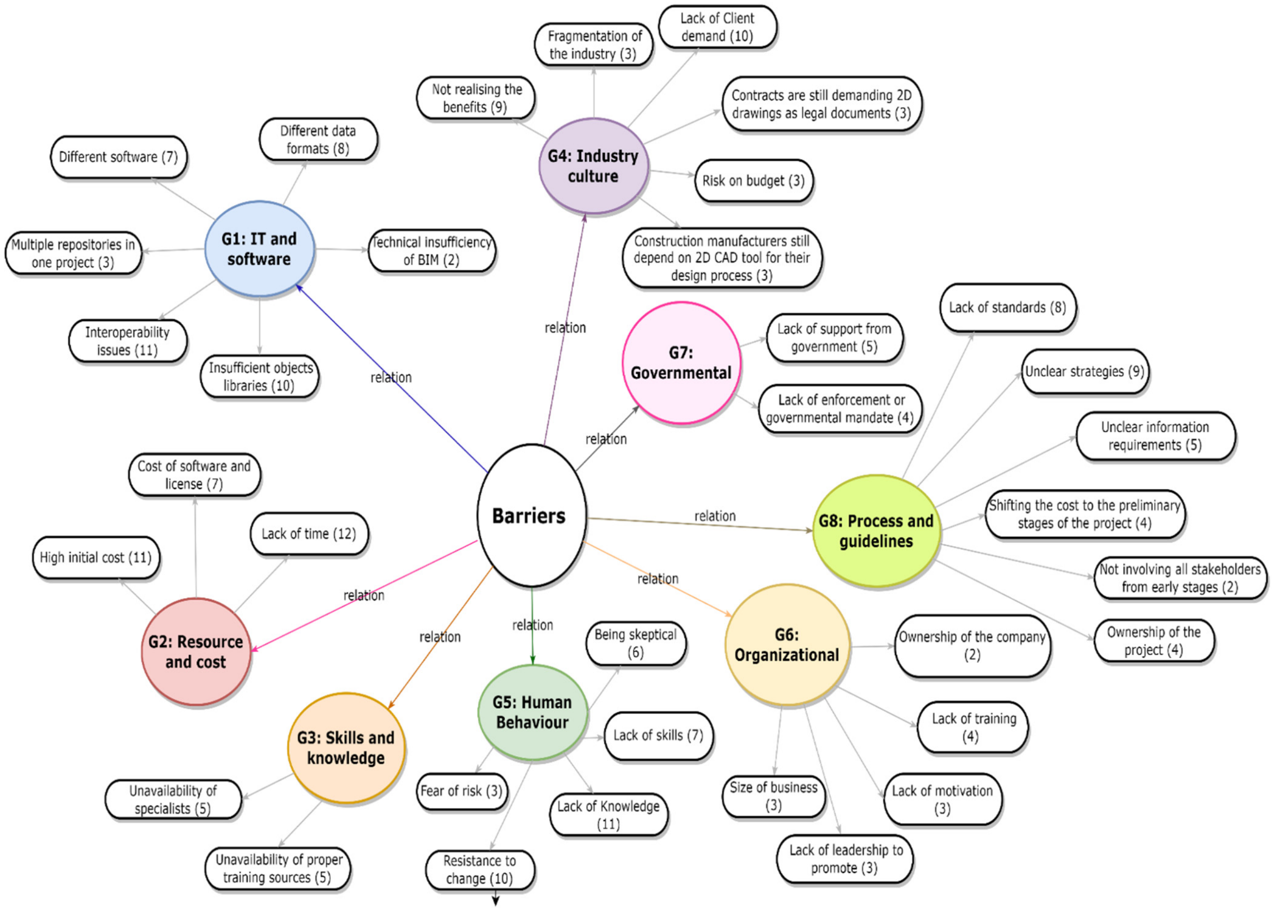

Figure 2. Coding map, Codes, Groups, and Categories.

3.4.1. Initial Coding (Open Coding)

Initial coding is an inductive activity. The purpose of this stage was to inductively generate as many ideas as possible from the raw data. Several nodes were identified, and preliminary categories were established. This stage also involved deriving patterns and searching for similarities. Several factors for low BIM implementation were mentioned by participants; these factors were initially classified and grouped into several nodes based on similarities and connections using various criteria for classifications.

The initial coding assigned a code (B#) to any barrier mentioned in the transcripts. The same code was given to similar factors; for example, if one factor was mentioned by several participants using different words, these factors were given the same code to avoid duplication. The initial coding resulted in the identification of 35 barriers, coded as B1 through B35.

3.4.2. Focused Coding (Axial Coding)

During the axial coding stage, decisions were made regarding the initial codes based on their prevalence or importance and on the extent of their contribution to the analysis. The factors were highlighted based on their importance and the frequency at which they were mentioned. The factors or barriers were also analysed in conjunction with other aspects, such as the background of the participant, the type of company, and the type of project. During axial coding, comparisons between codes were constantly made to find similarities and connections and to group factors.

Axial coding resulted in grouping the barriers into eight groups (G1–G8) based on the causes that these barriers stemmed from. The groups are shown in Figure 2. The number or frequency at which each barrier was mentioned during the interviews is shown in the figure as a number next to each barrier.

3.4.3. Theoretical Coding (Selective Coding)

In theoretical coding, the factors were refined into final categories in the theory, and relationships were drawn. The barriers at this stage were clearly defined and classified, and the data were considered ready to derive analysis results. Broader groupings and nodes were deduced at this stage. Selective coding produced three main categories for the barriers, as shown in Figure 2, which are C1: technology- and resource-related barriers; C2: people-related barriers; and C3: process-related barriers.

3.4.4. Second Round of Data Collection—Theoretical Saturation

After the first round of analysis and coding was finished, six more interviews were conducted, transcribed, and coded using the predefined codes from the first round. The coding in the two stages was carried out by different researchers to ensure the validity of the coding process. The aim of conducting the analysis in GT in multiple stages is to achieve theoretical saturation [57]. The first round of interviews was coded and analysed, and initial barriers were identified. In GT, several iterations are conducted using the same codes. After analysing the second round of interviews, it was noticed that all identified barriers already existed in the defined codes, meaning that the additional transcripts did not expand upon the previously analysed codes; hence, the mentioned barriers and factors were already identified, and the coding process was theoretically saturated.

3.5. Theory Building

After theoretical coding and achieving theoretical saturation, the analysis comprehensively identified barriers that are hindering the full implementation of BIM in the wood construction industry. This identification of factors and development of concepts in GT is known as the storyline method [57]. This storyline interpreted how companies are still facing barriers and difficulties that are limiting the move of the industry towards achieving the full potential of BIM in wood construction projects in Sweden. Participants in the interviews also shared possible solutions and suggestions to overcome these barriers, which complement the findings of the literature review and helped to derive and map the framework for BIM implementation barriers and the proposed solutions that this research recommends for the wood construction industry in Sweden.

4. Results and Discussion

The analysis of the interviews provided insights about the participants' perceptions of barriers that are hindering the implementation of BIM in the wood construction industry. Using the GT methodology, 35 barriers were identified and grouped into eight groups under three main categories.

4.1. Comparison between GT Results and Literature Review Results

The examination of the identified barriers compared with the results of the literature review revealed many similarities. Barriers related to resources and cost (G2) [36,49,55,62,63], skills and knowledge (G3) [9,21,29,31], human behaviour (G5) [44,49,55], and governmental (G7) [21,31,49] were all identified previously from similar studies in the literature review, as shown in Table 1. Other barriers were mentioned by participants and were found to be related to the wood industry in particular, such as interoperability issues [46,64] and insufficient object libraries (G1) [50].

Although similar barriers have been identified in the literature concerning the construction industry in general, wood construction practitioners have highlighted that interoperability issues between BIM software and wood manufacturing and fabrication still exist. Thus, efforts are being made to create a smoother information flow between design, manufacturing, and construction, including a seamless, direct flow of information between 3D models and CNC machines. However, several participants mentioned that manufacturers are still required to produce their own drawings and fabrication details, with a significant amount of rework in most cases, and the majority of wood fabricators still rely on 2D drawings for their cutting machines. Moreover, several participants mentioned that available object libraries for wood items are not sufficient; in particular, because wood objects require high levels of details, several participants stated that they still need to produce their own objects in some cases, which requires time and effort, and accordingly, decisions are made in some projects to create enlargements manually and in CAD rather than adding objects to the BIM model.

Other barriers related to industry culture were identified (G4). As the wood construction industry supply chain involves wood manufacturers and suppliers, the design and manufacturing integration process requires greater collaboration and introduces more challenges to the implementation of BIM, as manufacturers and wood fabricators work with different formats and software than consultants involved in the design phase. Other barriers were mentioned by the participants in relation to the wood construction industry concerning the sizes and types of businesses. Most wood construction industries in Sweden are small family-owned firms, following processes that have been adopted for years, and motivation for change is lower when compared to larger multinational firms. These eight groups of barriers are discussed in this section, and their corresponding codes are examined inductively.

4.2. Technology- and Resource-Related Barriers (C1)

4.2.1. G1: Information Technology and Software

Barriers related to IT and software were mentioned by most participants. Interoperability issues are still being faced, whether between different software or between project teams and stakeholders. Several data formats are still being used to exchange information, which results in data loss and wasted time. Some participants argued that BIM is not adequately suited for some disciplines due to its lack of capability to perform a specific task. One participant who works with structure analysis stated that IFC has low-quality geometry and that they find other formats and tools more suitable. Interestingly, some participants claimed that traditional methods, in some cases, such as small unique projects, can be more effective, such as sketching and using typical details from previous projects in AutoCAD, and as the vision of BIM requires that everyone be on board, the reluctance of one of the project teams to implement BIM will lead to missing information in the BIM model, and the usage of the model will be reduced. Efforts are still needed to address the IT-related issues of BIM; the seamless flow of data between project phases and along the supply chain will increase the effectiveness of the project, and better standardisation of data formats and guidelines should be achieved to overcome the issues of using different data formats and software between project stakeholders. The wood construction industry will benefit from solving interoperability issues between BIM models and CNC machines. Efforts should be made to enhance the available libraries of wood objects, which will lead to creating more informative BIM models in wood projects.

4.2.2. G2: Resources and Cost

There was disagreement between participants when related to the initial cost of BIM, the cost on the run, and whether this cost is worth the investment. BIM requires introducing new software, such as Revit, Tekla, and Navisworks, that can replace or be used in addition to traditionally used software, such as 2DCAD. Starting to use new software will impose changes on many levels, such as server capacity, device specifications, new licences, and IT personnel capabilities. Additionally, training to use new software will be inevitable and will require additional time and cost. The introduction of new software will involve changes to processes and ways of doing things, and transition periods can be messy and costly. Other participants reported that proper implementation of BIM will add more time to the work schedule; new time-consuming activities will be needed, such as adding objects and specifications to the model, and if a fully detailed model is not requested by the clients, designers will often disregard such details. We conclude that evidence of BIM's feasibility is required, and more research should be conducted to measure the return on investment in BIM at the level of projects and the organisation's performance. Proof of the benefits of BIM for saving time and cost is needed to make it more appealing for investors to take the step.

4.2.3. G3: Skills and Knowledge

Any company that decides to shift their processes towards implementing BIM will require either hiring new specialised staff or training their own, and sometimes both. Some participants mentioned that proper training for BIM can be hard to find and that skilled technicians can be hard to find.

4.3. People-Related Barriers (C2)

4.3.1. G4: Construction Industry Culture

The construction industry has been criticised by participants for being fragmented and reluctant to change. Moreover, the industry profit margin is sensitive, and companies will avoid any risk when it comes to cost. The industry is resistant to change, construction contracts are still demanding 2D drawings as a project deliverable, and the lack of demand for BIM from clients is still noticeable. The industry needs to realise the benefits that BIM offers for decision makers to change their mindsets and accept the change. Accepting a BIM model as a legal project document in the contract might reduce the need for producing 2D drawings in every project.

4.3.2. G5: Human Behaviour

Similar to industry culture barriers, a change in the mindsets of human resources in the industry is needed. Taking the lead towards change needs to come from management, and resistance to change from all people involved should be reduced by increasing the knowledge about BIM and developing the skills of human resources, which will reduce the fear of risk and encourage people to take steps towards new technologies and development.

4.4. Process-Related Barriers (C3)

4.4.1. G6: Organisational

At an organisational level, some barriers were attributed to the fact that Swedish wood construction companies are relatively small and, in most cases, have been owned by families for generations. Barriers such as lack of leadership and reluctance to change can have a higher effect in small companies. Some participants claimed that the ownership of the project can be a barrier to BIM implementation and that this is a norm that can be seen in wood construction projects where the entire project process is handled in-house. When the design, production, and construction of the project are handled by the same company, the need for integration processes and advanced communication systems becomes less necessary, and accordingly, these companies will not be very tempted to change their methods of working to adopt BIM, unless it is required by other stakeholders, such as clients of facility managers.

4.4.2. G7: Governmental

Most participants stated that they were not aware of any BIM government mandates in Sweden, and there was disagreement among responses on whether government enforcement is required. The move towards BIM in the Swedish wood construction industry was initiated and supported by industry representatives and alliances with little governmental participation. However, the involvement of the public sector and official mandates and requirements from authorities, similar to other countries, can facilitate, speed up, and organise the move towards BIM. Other acts of government support can be funding BIM initiatives, providing training and technical support, and mandating BIM at least in public construction contracts.

4.4.3. G8: Process and Guidelines

Unclear information requirements and unclear strategies were frequently mentioned barriers among participants. Several participants stated that, often, companies do not know how to start implementing BIM and that clear BIM implementation processes and guidelines are not available. A participant from the BIM alliance stated that current efforts are being put towards issuing BIM standards in Sweden, which is believed to address several issues related to data formats and requirements. The need for clear official standards is evident to achieve more efficiency in BIM implementation.

Other barriers concerning the construction industry process were mentioned by participants, such as not involving all stakeholders from the initial project stages, especially wood manufacturers and facility managers. Some participants revealed that the reason behind this late involvement is due to procurement strategies and cost issues, in which suppliers are rarely identified in the concept stage, and thus, to avoid commitment with other parties, the involvement of material vendors in most cases comes after finalising the design, which entails abortive works and additional hours and efforts from these stakeholders. On a similar note, several participants reported that one of the reasons for not implementing BIM properly is that proper implementation will require increasing efforts in the preliminary stages of the project. The traditional method of project design usually starts with a concept stage with simple plans and sketches, and minimal cost and effort will be utilised at this stage, as the project budget is still unclear and negotiations are being carried out. Having to produce a BIM model with sufficient details at this stage will pose risks to budgets and will move the cost from later stages to upfront in the cost plan.

The three categories and their corresponding barriers illustrated above are complementary and synergistic. The proper implementation of BIM will require overcoming barriers from the three categories simultaneously. Figure 3 illustrates a conceptual model showing the relationship between the three theoretical categories and the recommended solutions extracted from the research analysis.

4.4.4. C1: Technology- and Resource-Related Barriers

The construction industry is found to be conservative when it comes to adopting new technologies, and the wood construction industry is not an exception. As the results of the research revealed that adopting BIM will entail issues related to resources, systems, and costs, overcoming these barriers will pave the way for more companies to join the shift towards BIM. BIM utilisation might be initiated by hiring expert staff to set guidelines and work maps and to train the company's staff on new software and methods. The efforts for standardisation under category C3 will aid in overcoming barriers related to data exchange and requirements and provide a clearer path for newcomers.

4.4.5. C2: People-Related Barriers

Overcoming barriers related to resources and information technology (C1) will facilitate overcoming people-related barriers. People will be less likely to resist a change that they believe is efficient and necessary and will find the move toward BIM more appealing when they do not face technical and resource obstacles. Some participants suggested that companies move towards implementing BIM in small steps rather than substantially shifting all at once. This will lighten the burden and will facilitate the transitional period. The results of the research showed a serious need for evidence of tangible outcomes of implementing BIM, and more research should focus on measuring the rate of investment in BIM through actual case studies that will encourage construction industry stakeholders to invest in BIM.

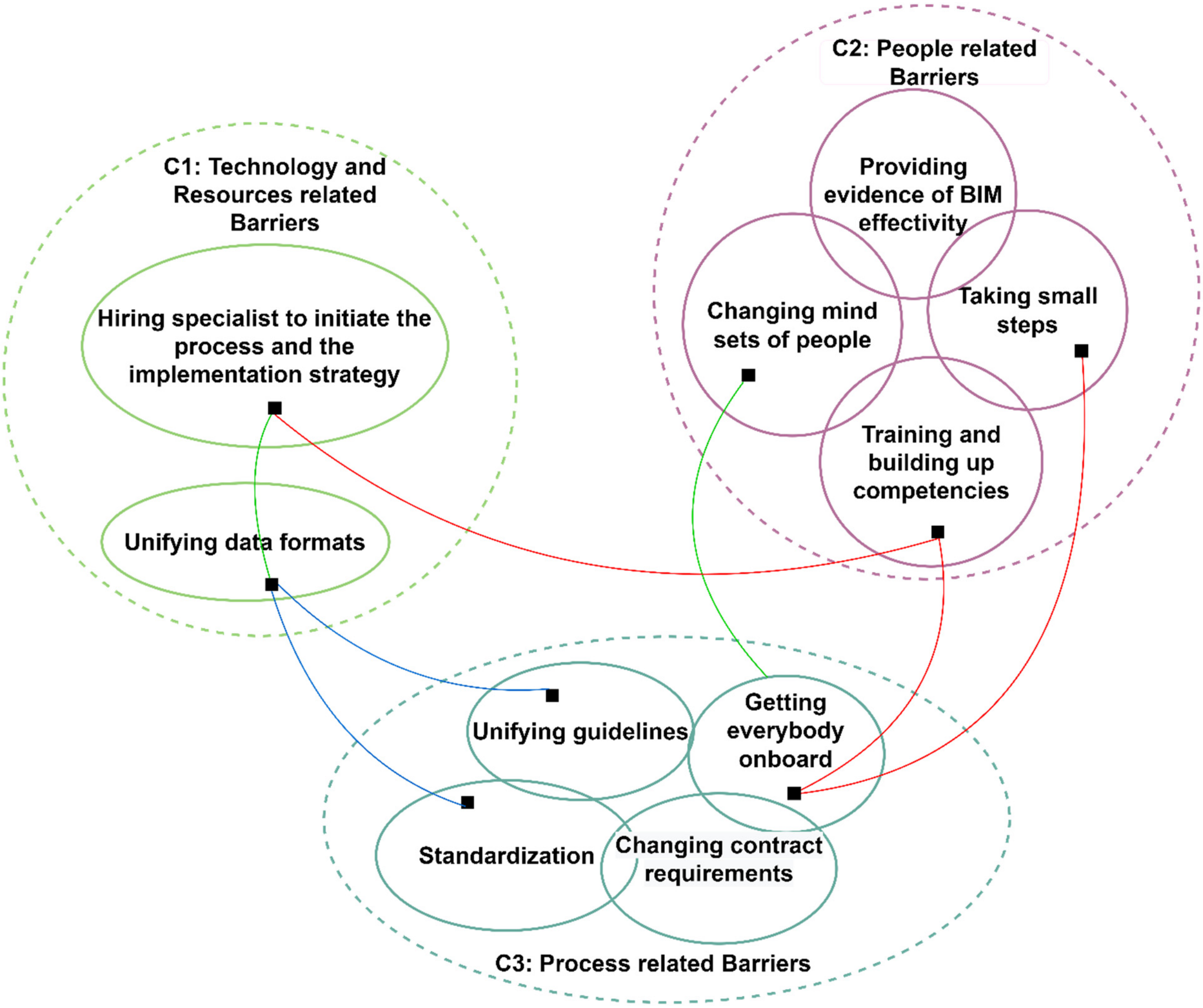

Figure 3. The proposed conceptual model to overcome BIM implementation barriers.

4.4.6. C3: Process-Related Barriers

Several participants stressed the need for official standards for BIM. The lack of standardised processes and guidelines is the main cause of ununified format and interoperability issues (C1). Clear guidelines for BIM implementation are needed, among which a mandate for getting everyone on board in the project should be emphasised. The involvement of all stakeholders throughout the project lifecycle will minimise the issues of resource allocation and double efforts (C1) and will encourage several participants in the project supply chain to be involved in the BIM process, which will increase the level of BIM implementation in the long run in the industry (C2).

5. Conclusions

The level of BIM implementation varied among different businesses, and its implementation commenced at different maturity levels and stages, ranging from no utilisation at all to being used to some extent. Although many entities and organisations are striving towards excelling in BIM and are showing extraordinary interest in it, barriers still exist and are creating obstacles in the way forward.

The reluctance of the wood construction industry to adopt BIM is evident, and research on BIM implementation in wood construction is scarce. Additional research is needed to identify the reasons behind the slow adoption in the wood construction industry in Sweden. Thus, the contributions offered by the present paper are twofold: barriers were identified through a robust review of research in the wood industry context and refined (semi-structured interviews) through the lenses of experts in Sweden. Secondly, the study offers a road map (considering the identified barriers) for industry stakeholders to move toward more digitalised wood construction in Sweden. In addition to these contributions, the study highlights opportunities for decision makers to encourage the wider adoption of BIM in the wood construction sector. The study results show that interoperability issues, insufficient object libraries, lack of time, high initial cost, lack of knowledge, and resistance to change are the main issues that require the utmost attention. Thus, the following recommendations can be made with consideration of the barriers identified in this study:

1. The wood construction industry should focus on solving interoperability issues between BIM models and CNC machines. Efforts should be made to enhance the available libraries of wood objects, which will lead to creating more informative BIM models in wood projects.
2. More research should be conducted to measure the return on investment in BIM at the level of projects and the organisation's performance. Proof of the benefits of BIM for saving time and cost is needed to make it more appealing for investors to take the step.
3. The industry needs to realise the benefits that BIM offers for decision makers to change their mindsets and accept the change. Accepting a BIM model as a legal project document in the contract might eliminate the need for producing 2D drawings in every project.
4. There is a need for government efforts to standardise BIM implementation to overcome barriers related to data exchange and requirements and provide a clearer path for newcomers.

Notwithstanding the contributions that are presented in this research, acknowledging the limitations is essential prior to deriving any conclusions based on the findings. The results should be considered with caution, as they are based on the feedback of industry experts in Sweden, which may introduce operational and social disparities related to wood construction practices. Future research could possibly investigate barriers to BIM adoption in the wood construction field within other countries and compare findings. Additionally, to offer more generalisable findings, future researchers are recommended to explore the barriers to BIM adoption using probability sampling techniques. Finally, the root causes of the barriers, any possible interconnections between them, and possible strategies to overcome them could be further explored in future research.

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