TRUST AND COLLABORATION PROBLEMS IN BUILDING INFORMATION MODELLING (BIM): A SYSTEMATIC LITERATURE REVIEW

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Abstract. Building information modelling (BIM) has been proposed to address collaboration issues. Trust is a key factor in facilitating collaboration and improving construction industry productivity. Therefore, this study detected 22 trust issues based on a systematic literature review of trust and collaboration research in BIM. The comprehensive consideration of what issues affect trust and collaboration in BIM projects will help to analyse whether these issues are related and finally give reasonable suggestions on how to address these issues.

1. Introduction

Collaboration and trust have been researched for over 20 years in the UK construction industry (Barron, 1995). Since the 1990s, the UK Oil and Gas Industry has been promoting standard methods of doing things, rather than the practices that the industry has accustomed to, to achieve cost reductions (Barron, 1995). Barron (1995) argued that behaviour cannot be changed without trust to persuade people to follow new standards.

Building information modelling (BIM) is proposed to improve collaboration (Khosrowshahi and Arayici, 2012). However, collaboration in the construction industry is still inefficient, even if BIM has been implemented for over a decade (Koutamanis, 2020). To identify what issues hinder the implementation of BIM, this research focuses on identifying trust issues.

An agreement is that trust could generate harmony and respect within project teams (Davis and Love, 2011) and the most important role of trust is that it could promote collaboration (Ahiaga-Dagbui et al., 2020). Because good partnerships are built on trust, which could be enhanced by effective communication, contributing to a successful collaboration (Doloi, 2009).

Based on a critical review of the literature on trust and collaboration problems in BIM, this research aims to answer the following research questions:

- What are the meanings of trust and collaboration in BIM-enabled projects?
- What are the problems of trust and collaboration in BIM-enabled projects?
- What is the importance of identifying these problems?

2. Methodology

This research uses a systematic literature review to identify trust and collaboration problems in BIM. A standard PRISMA Flow Diagram is used, including four steps: (1) identification, (2) screening, (3) eligibility, and (4) inclusion Moher et al. (2009). The process for this research is shown in Figure 1.

The main database is Scopus. After comparing the search result among Scopus, Google Scholar, and Web of Science, the results of the three databases are highly repeatable. Therefore, carefully considering the search results, this research chooses Scopus as the main database. All research results come from the top 25% of journals related to the construction industry in Scientific Journal Rankings, named Q1 journals. Keywords choices for “trust in BIM” and “collaboration in BIM” are shown below.

- Trust in BIM

Keywords: TITLE-ABS-KEY(("BIM*" or "Building information modelling*") and "trust*") and ISSN in Q1 journals. Results before exclusion criteria: 21 documents.

- Collaboration in BIM

Keywords: TITLE-ABS-KEY(("BIM*" or "Building information modelling*") and "collaboration*") and ISSN in Q1 journals. Results before exclusion criteria: 164 documents.

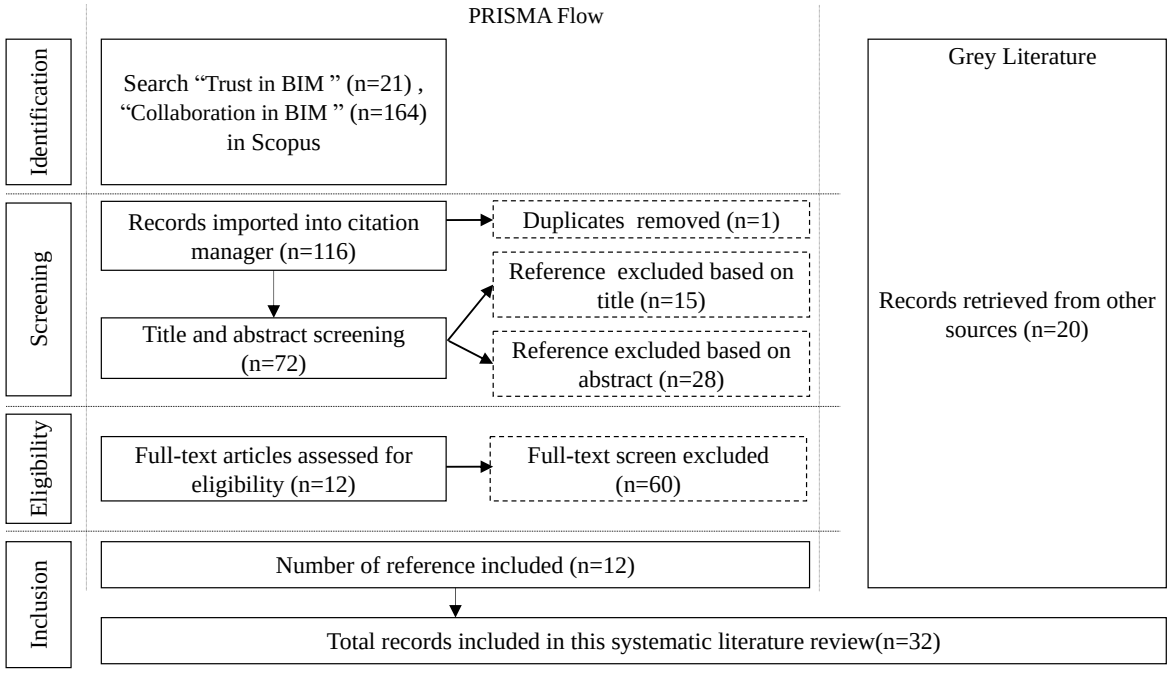

Figure 1 PRISMA Flow for this research

Besides, there are some inclusion and exclusion criteria for selecting this systematic literature review, as shown in Table 1.

Table 1. Inclusion and exclusion criteria

Criteria	Step	Databases	Grey literature
Inclusion	Identification	Peer-reviewed journals, conference proceedings, books, and dissertations.	English language.
Exclusion	Identification	Non-English language: Reference published before 2010 (note: no time limitation for landmark research).	Not relevant to this research topic; Before 2010.
	Screening	Title or abstract shows low relevance to the scope of the research.	
	Eligibility	The full paper is not relevant to this research topic.	

Table 2. Checklist for validating data reliability

No.	Criteria	Yes	No	Unclear	N/A
1	Is the literature complete? (e.g., no missing chapter)				
2	Is the aim/objective of the study clearly described?				
3	Is there enough literature or data to support the conclusion?				
4	Is the method of study selected suitable for the study problem?				
5	Is the author authoritative?				
6	Is the publisher authoritative?				

According to Creswell (2011), the accuracy and reliability of the literature should be identified before analysing the data and drawing conclusions. Therefore, the criteria in Table 2 are built up to validate the reference reliability.

In terms of the first four criteria, literature was considered a not reliable source if the answer was not “Yes”. Regarding the other two criteria, the literature was regarded as a relatively essential supporting reference and should be analysed carefully if the answer was “Yes”. The study also included literature if the answers to these two articles were not "Yes". The literature would be valuable if the first four criteria were met because relevant research consistent with this study is insufficient.

3. Trust and collaboration in a BIM project

3.1 Trust is a vital part of collaboration

There are some arguments about the content of collaboration. Some research advocate collaboration consists of several factors. For example, Schöttle et al. (2014) figured out some static factors of collaboration, such as willingness to compromise, communication, commitment, trust, transparency/information exchange, knowledge sharing, and willingness of a client to take a risk, as shown in Figure 2.

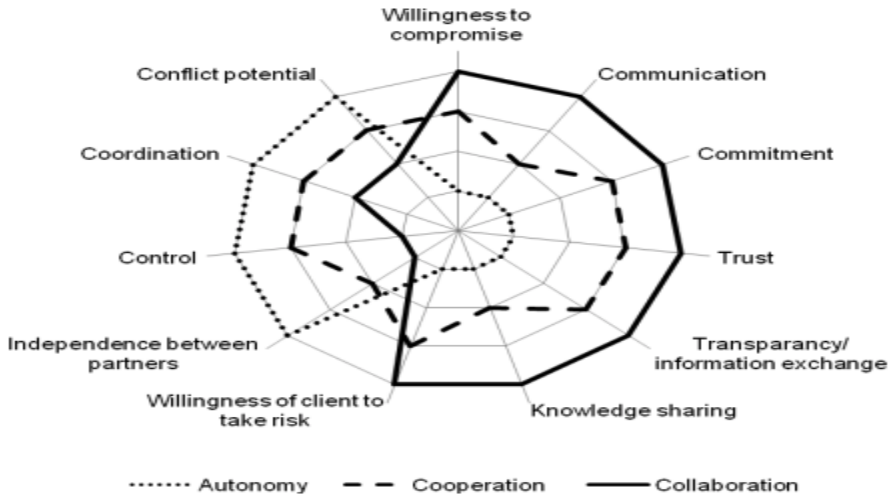

Figure 2. Compromise the terms cooperation and collaboration (Schöttle et al., 2014)

Some researchers only focus on a few aspects. For example, Smyth and Pryke (2009) argued that collaboration could be considered in terms of the structure of a team. Their research mainly focused on contractual mechanisms and relationships and the influence of collaboration on team outcomes (ibid). They argued that the result of their research helps to improve partner relationships and strengthen supply chain management. Besides, Chiocchio et al. (2011) considered collaboration from a process perspective, such as managing conflict and building trust based on teamwork. They argued that there is a positive impact between building trust and promoting collaboration.

A relatively comprehensive definition of collaboration was proposed by (3) Poirier et al. (2017), who argue that collaboration should not simply be considered in terms of different factors or aspects. Instead, collaboration should be conceptualised as a system of four interacting core entities (ibid): structures, processes, agents and artefacts, governed by a fifth factor: context, as shown in Figure 3.

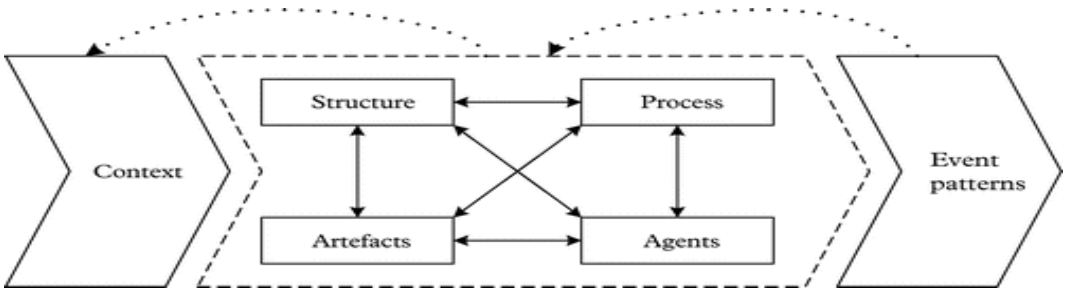

Figure 3. The collaboration system (Poirier et al., 2017)

Apart from the disagreement about collaboration, one consensus is that trust is an indispensable part of collaboration. Smyth and Pryke (2009) argued that developing trust helps to strengthen cooperation. Similarly, Liu et al. (2021) claimed that trust is a core bond of collaboration between different organisations. Therefore, the execution of an appropriate formal or informal contract is a benefit for building trust and developing collaboration.

However, the above arguments are descriptive. They have not offered an adequate explanation for the relationship between trust and collaboration. A more specific explanation was proposed by (Oraee et al., 2021). They figured out four detailed factors impacting collaboration in BIM-based construction networks. Trust is one of the four factors; The other three are BIM execution plan, liability, and intellectual property and ownership.

Table 3. Five perceptual determinates of an individual, adopted from Mohammed (2020) and Poirier et al. (2017)

Expectation	The expectation is related to an expected event's result or aim. It comes from an informal or intangible source of motivation.
Requirement	The requirement corresponds to the obligation. Moreover, the importance of different requirements varies. A common difficulty in collaborative projects is the lack of precise requirements.
Intention	The intention is the proactive commitment to achieving a plan after its development.
Capability	Capability refers to a person's objective ability to achieve a specific goal and the individual's perception of their capability (self-effectiveness).
Incentive	Incentives can be financial gains or reputational incentives. The purpose of incentive is to anchor commitments and intentions. But it could produce a negative effect on an organization or project.

Besides, referring to some arguments about collaboration and the definition of trust, an inference could be drawn that trust is a part of collaboration. Several references mentioned that the "five perceptual determinates of an individual" are the dynamic factors that form the basis for influencing construction collaboration (Mohammed, 2020, Poirier et al., 2017), shown in Table 3. Moreover, Trust is a positive expectation about others' intentions or actions (Sahay, 2003). It could be found that this definition of trust is similar to the explanations of "expectation" and "intention" in Table 3. These five perceptual determinates are related to developing collaboration. So there might be a close relationship between trust and collaboration. It is true that many studies on collaboration identify trust as a key factor influencing collaboration (Chiocchio et al., 2011, Phua, 2013).

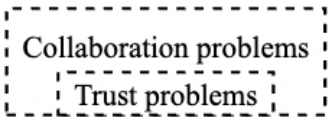

Figure 4. Relation between collaboration and trust (adopted by the author)

In sum, collaboration is influenced by several factors, while trust could be seen as a part of the collaboration (Chiocchio et al., 2011, Schöttle et al., 2014). The relationship between trust and collaboration is shown in Figure 4. This research will then refer to collaboration problems encountered in a BIM project. In this research scope, there is a sufficient and comprehensive research, which could be regarded as an additional reference for trust problems of BIM.

3.2 Trust and collaboration problems in BIM

After using a systematic literature review about trust issues and collaboration issues of BIM in the UK construction industry, this paper found only a few research focus on trust issues in recent years. Among these researches, Piroozfar et al. (2019) and Shojaei et al. (2022) comprehensively identified trust issues in BIM. Piroozfar et al. (2019) claimed the most significant barriers to building trust include "conflicting interest, arrogance, ignorance, poor organisation and leadership, bad planning, wrong work culture (aggressiveness, humiliation, instilling fear), and parties' fragmentation", while Shojaei et al. (2022) summarised the practical recommendations to convince clients about the implementation of BIM into five aspects: (1) "honest communication"; (2) "reliable information about the inherent risks and benefits associated with these innovations"; (3) "meeting expectations regarding the use of BIM"; (4) "having mutual respect for values"; and (5) "maintaining a good reputation by adhering to contractual requirements".

Although there are few studies on trust issues in the UK construction industry, research about collaboration could be regarded as a reference for this trust research. Because trust is a part of the collaboration (Schöttle et al., 2014), there are some overlaps between trust problems and collaboration problems. Besides, collaboration problems are reviewed more comprehensively in academics than trust problems. To explore trust problems more sufficiently in the data collection stage, this research uses collaboration problems as supplementary factors to explore trust problems. 22 trust and collaboration issues are identified as follows.

Issue 1: Bad reputation for breaching contract. Shojaei et al. (2022) summarised the practical recommendations to convince clients about the implementation of BIM into five aspects: (1) "honest communication"; (2) "reliable information about the inherent risks and benefits associated with these innovations"; (3) "meeting agreed expectations regarding the use of BIM"; (4) "having mutual respect for values"; and (5) "maintaining a good reputation by adhering to contractual requirements". Shojaei et al. (2022) claimed that maintaining a good reputation helps win the trust of clients.

Issue 2: Unpleasant previous experience collaborating on a BIM-enabled project. Issue 3: Lack of awareness of the benefits of collaboration. Issue 4: Negative working culture (aggression, humiliation, fear) in construction projects. In a BIM project, Piroozfar et al. (2019) argued that an arrogant attitude towards each contractor and consultant and lack of awareness of the benefits of collaboration are unpleasant personal experiences. These unpleasant experiences may hinder the development of a positive emotional connection between stakeholders. Team atmosphere significantly impacts teamwork efficiency, including work environment comfort, interpersonal interaction behaviour and teamwork efficiency (Wang et al., 2021). For example, wrong work culture, such as aggressiveness, humiliation, and instilling fear, may play a negative role in building trust (Piroozfar et al., 2019).

Besides, due to lack of expectations to use BIM, team members lack the motivation to undertake BIM training (Shojaei et al., 2022), which leads to a lack of skills among team members (Oraee et al., 2021).

Issue 5: Lack of knowledge or experience in BIM (knowledge, skills, and abilities of individuals). Wang et al. (2021) mentioned that the characteristics of team members affect the efficiency of collaboration, such as work attitude, learning ability, professional competence, and work

experience. Especially a common difficulty in BIM model development is the lack of personnel with sufficient knowledge to develop and check the model (Lin et al., 2020).

Issue 6: Lack of trust in BIM data (risk of data breaches and tampering. In a BIM project, data immutability cannot be guaranteed. Because the BIM-enabled collaboration requires the team members to share building information on the BIM platform (Ghaffarianhoseini et al., 2017). It gives unauthorised users a chance to steal and tamper with BIM data. Moreover, the network adaptability of the BIM platform is imperfect in protecting data security (Nawari and Ravindran, 2019). Therefore, the authentication mechanism on a BIM platform is not reliable enough to prevent data tamper by network attacks (Erri Pradeep et al., 2019).

Issue 7: Ownership of the BIM model is unclear (e.g., Difficulties in defining and protecting intellectual property). The issue of property rights in the construction industry is a major challenge in applying BIM to facilitate collaboration (Ardani et al., 2021). Specifically, the current use of BIM to transfer and share information does not ensure a trusted environment to protect data ownership and intellectual property (IP) (Saini et al., 2019). Moreover, most industries commonly protect digital property rights by sacrificing data accuracy (Nawari and Ravindran, 2019). As a result, property rights become a neglected issue in the construction industry (Adibfar et al., 2020).

Issue 8: BIM fails to meet all project task requirements due to functional deficiencies in BIM software (e.g., some tasks require non-BIM tools to complete). Mohammed (2020) claimed that the lack of interoperability between BIM software affects collaboration in BIM projects. For example, the construction of BIM models relies on commercial design tools, which inevitably have some functional deficiencies in practice (Oh et al., 2015). Therefore, in some cases, designers should cooperate with software suppliers to improve software functions to meet business needs through secondary development according to their own business needs.

Issue 9: Conflicts of interest among stakeholders. Conflicts of interest and inherent risks in BIM projects can lead to mistrust between stakeholders (Piroozfar et al., 2019).

Issue 10: In resolving BIM-related disputes, current contracts favour main contractors (with more resources) against subcontractors. *Issue 11: BIM-related clauses in current contracts do not equally distribute potential risks and benefits between stakeholders.* The design of contracts has legal shortcomings (Ardani et al., 2021). For example, disagreements due to poor contract design in case of infringement of intellectual property rights or data ownership deepen the problem of collaboration in BIM. In addition, Chan et al. (2019) claim that the lack of transparent contracts between different disciplines also affects collaboration. A non-transparent contract means that the responsibilities and obligations of team members are not clearly outlined. This kind of untransparent contract fails to help team members share the project's risks while ensuring their benefits.

Issue 12: Lack of precise specifications for the level of detail/information in BIM models. The information exchange process in BIM has some flaws when collaborating with a third party or in cross-professional design (Liu et al., 2017). Specifically, there is no precise specification about the level of detail in most shared BIM models (Redmond et al., 2012), which leads to collaboration barriers between different stakeholders.

Issue 13: Lack of standards for managing and maintaining information contained within BIM models. Repetitive tasks in a BIM project often occur when different stakeholders operate in the same BIM environment. For example, during different construction stages, various creation and maintenance standards of a BIM model lead to incompatible modelling practices between different stakeholders, which makes BIM-enabled collaboration a time-consuming and wasteful effort (Ahn et al., 2016).

Issue 14: Inappropriate implementation of the BIM execution plan (BEP). In BIM-based collaborative design, vague or unreasonable assignment of tasks among members can lead to difficulties in collaboration and task execution across disciplines (Wang et al., 2021). Wang et al. (2021) specified the problems in BIM design tasks, such as unclear task requirements, unclear task importance, poor task feedback mechanism, discontinuity in task design, and unreasonable task feasibility. The task design problem is mainly the unclear design of the BIM execution plan (BEP), such as the inappropriate arrangement of specific responsibilities and rights of personnel from different disciplines and the schedule (Oraee et al., 2021). These irrationalities may lead to insufficient time to develop and check the model and cause difficulties in updating and modifying the model (Lin et al., 2020). Furthermore, it means the arrangement of design tasks may negatively affect team productivity and collaboration (Jimmieson et al., 2017).

Issue 15: Data loss during data transmission between multiple BIM software (Revit, Navisworks or InfraWorks, etc.) or platforms (Autodesk, Bentley, or Catia, etc.). Data integrity is damaged due to the limited technical support in BIM models. Data integrity might be affected when entering and extracting information from the BIM environment (Liu et al., 2017).

Issue 16: Lack of data traceability for model revisions and handover data between design, construction, operations and maintenance stages. Data non-traceability is caused by designer behaviour patterns in a BIM project. For example, the designer is only responsible for the BIM model before the construction stage, while they have no responsibility or obligation to modify it after the design stage (Liu et al., 2017). This bad planning might lead to untraceable BIM models between different construction stages. For example, the storage and delivery of construction materials involve multiple stakeholders, and it is difficult to monitor construction activities and manage CSC with a single BIM. However, these different stakeholders do not sufficiently engage with each other (Hijazi et al., 2021). In such a case, they can only rely on a single BIM model with insufficient construction data to make decisions (Penzes et al.).

Issue 17: Lack of transparency in communications and key decision points for information modelling. Lack of honest communication between team members in a BIM project is another problem to hinder the development of trust (Shojaei et al., 2022). The centralised framing of BIM has led to transparency barriers (Deng et al., 2019, Hijazi et al.). Oraee et al. (2021) suggested that establishing transparent relationships in BIM projects where stakeholders are comfortable exchanging data and providing the information is a prerequisite to effective collaboration. However, there is no trusted platform or reliable intermediary to support data exchange in the construction supply chain in BIM projects (Penzes et al.). It means it is difficult to develop effective interactions in the centralised framing of BIM.

Issue 18: Adversarial supply chain relationships (e.g., between superiors and subordinates, between different stakeholders, or supply-demand relationship). Issue 19: Organisational complexity of multidisciplinary teams makes it difficult to build trust for BIM-enabled collaboration. Issue 20: Highly fragmented construction supply chain hinders the ideal use of a shared BIM model and efficient data exchange. The high level of fragmentation in the built environment may lead to collaboration problems in a BIM project. Ardani et al. (2021) emphasize that different organizational structures in multidisciplinary teams can further deepen the collaboration difficulties in a BIM project.

Issue 21: Lack of incentivisation for small and medium enterprises to use BIM. Issue 22: Lack of support for implementing BIM. When small and medium-sized organizations face difficult and complex BIM projects, they often outsource because their design habits and management methods are difficult to adapt to complex projects (Bui et al., 2016). In contrast, large organisations have their R&D teams, which enables them to cope with complex design requirements.

4. Discussion

4.1 Importance of defining trust and collaboration

Definitions and relationships of trust and collaboration contribute to delineating the scope of trust and collaboration issues. First, this research defines what is trust and what is collaboration. If the scopes of trust and collaboration have not been described before identifying issues, it is hard to classify what is a trust or collaboration issue.

Second, this research emphasises that trust is a key part of the collaboration (Putnam, 1993, Schöttle et al., 2014). Due to insufficient references for detecting trust issues in the BIM project, this research reasonably uses collaborative issues to complement trust issues. At the beginning of the literature search, not enough publications on trust were found, with only 21 publications returned based on keywords "(("BIM*" or "Building information modelling*") and "trust*") in Q1 journals". Therefore, it is not sufficient to serve as the database of a systematic literature review before exclusion criteria. Regarding the relationship between trust and collaboration, trust issues are included in collaboration issues. In this research, another 164 documents were found as the reference database using "(("BIM*" or "Building information modelling*") and "collaboration*") in Q1 journals" as keywords. In the end, a total of 185 publications served as the initial database for the systematic review before the exclusion criteria. This adequate reference database can more convincingly detect all crucial trust issues in BIM-enabled collaboration.

4.2 Significance of identifying trust and collaboration issues

Knowing what trust issues there are helps to resolve them more efficiently. The need to improve the level of BIM-enabled collaboration has been advocated in the construction industry (Gorse, 2020). Still, there is not a unified understanding of what is a collaboration issue and what is a trust issue. This systematic literature review revealed a lack of research on trust issues in the BIM project. One possible reason for the stagnant efficiency of collaboration in the construction industry is that it simply does not know the trust issues and collaboration problems (Qian and Papadonikolaki, 2020). If the construction industry or company do not know where the problem is, how can they propose targeted and effective solutions?

Besides, a comprehensive review of trust issues can help to identify commonalities between different issues. The 22 trust issues identified in this study can be classified into different categories based on common characteristics. Different solutions can be targeted to fit the different types of problems. For example, issue 15 "Data loss during transmission", issue 16 "Data untraceability", and issue 6 "Data unsecurity" might be solved by applying new technologies (Hijazi et al.). Furthermore, issue 3 "Lack of awareness of the benefits" and issue 5 "Lack of knowledge" might be solved by training and education (Zhang et al., 2017). Besides, issue 11 "Poor contract design" and issue 18 "Adversarial supply chain relationships", might need government, legal systems, and industry bodies to work together to drive change (Rashed and Mutis, 2023).

5. Conclusion

BIM is proposed to solve collaboration issues in the construction industry. However, so far, BIM has not met the high expectations of radically improved collaboration. As a key enabler of collaboration, trust is an important topic to be researched to improve BIM-enabled collaboration. However, there has been a paucity in this area of research.

This paper critically reviews the trust and collaboration literature in construction, to discuss the meaning and problems of trust in BIM-enabled collaboration. The systematic literature review identifies 22 trust and collaboration problems, which helps capture the nature of trust in BIM-enabled collaboration and propose targeted solutions. However, a limitation of this review is some issues are derived from research on BIM collaboration. Therefore, whether all 22 issues

are related to trust is not validated. In such a case, a questionnaire will be used in the next research step to verify whether they are trust issues.

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