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# TOWARDS A THEORETICAL FRAMEWORK OF TRUST IN BIM-ENABLED COLLABORATION

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## Abstract

Building information modelling (BIM) has not met the expectations of radically improved collaboration. As trust is a key enabler of collaboration, it is important to understand and address the trust issues in BIM-enabled collaboration for further improvement. Through a literature review on trust in psychology, economics, construction, and virtual collaboration, this paper enquires into the meaning and dimensions of trust. It is argued that the six dimensions of trust established in psychology and economics, the interrelationships between these dimensions, as well as the different units of analysis, need to be considered holistically for the study of trust in BIM-enabled collaboration.

## Introduction

In "A dictionary of construction, surveying and civil engineering", Building Information Modelling (BIM) is defined as a collaborative process for planning, designing, constructing, and maintaining the built asset by creating multi-dimensional computer models from the beginning to the end of a project lifecycle (Gorse, 2020). Similarly, (Khosrowshahi and Arayici, 2012) state that BIM's main mission is to enhance collaboration. However, the implementation of BIM has not met the high expectations of radically improved collaboration (Miettinen and Paavola, 2014). Because trust is a key enabler for collaboration (Doloi, 2009), arguably, BIM-enabled collaboration can be improved by better understanding and addressing the relevant trust issues.

Trust is a fundamental component of collaborative activities, as it promotes the social communication of people (Putnam (1993). For this reason, in construction research, the topics of collaboration and trust have been researched for over 20 years (Barron, 1995). For example, Latham's report (Latham, 1994) summarised the reasons why the productivity in construction is low and advocated for better collaboration between the construction companies. In 2020, a report from Thomas and Bowman (2020) established the cost of developing trust in companies and projects, and found that organisations operating in a high-trust environment increase their profits. However, despite the general interest in the topics of trust and collaboration in construction, there is only a small number of studies that explicitly focus on the trust issues in BIM-enabled collaboration. Therefore, currently, there is very limited understanding of trust issues in BIM-enabled collaboration.

Based on a critical review of the literature on trust in psychology, economics, construction and virtual collaboration, this paper explores the meaning and dimensions of trust in the context of BIM-enabled collaboration. The research questions that guided the literature review are 'what kinds of trust problems exist in BIM-enabled collaboration?' and 'what can be an adequate theoretical framework to study trust in BIM-enabled collaboration?'. The trust dimensions that are found to be relevant provide a conceptual foundation for building a theoretical framework of trust in BIM-enabled collaboration.

## BIM-enabled collaboration

The term, Building information model, was first proposed by van Nederveen and Tolman (1992). They claimed that BIM was an approach "to provide a simple and natural way to model building information (ibid)". More recent research shows the use of BIM is more than being a model or database for a project (Penzes, 2018). BIM is a digital working method to manage the input and output of an information management system (ibid). The emphasis of BIM is shifting from recording project data to managing data and making decisions.

There are two main arguments about the implementation of BIM in the industry. Some researchers argue that BIM is a key solution to increasing productivity in construction by solving collaboration problems (Khosrowshahi and Arayici, 2012). Even though some collaboration problems have not yet been addressed by BIM, the argument is that BIM would live up to the high expectations with the development of new technology, new policy, and a new construction environment. The governments worldwide also support the development of digitalisation in construction. One example from the UK is the BIM mandate which requires the suppliers of government projects to prove they have implemented BIM to a certain extent (Moore, 2020).

However, another opinion in the industry is BIM does not solve the problems that it is supposed to solve, while the resources invested in implementing BIM in construction projects are huge and the return on implementation is difficult to measure. As a result, many small and medium-sized companies in the construction industry are not willing to invest the resources to support the use of BIM (Koutamanis, 2020).

Overall, there seems to be a consensus that BIM has not yet realized its full potential in terms of the improvements to collaboration. A better understanding of trust issues in BIM can help BIM to better achieve its intended effect and enable more significant improvements in collaboration in the construction industry.

## Trust problems in BIM

This section presents the trust issues found in the existing BIM literature under eight categories. Each category is briefly explained below.

- Data security

Unauthorised users might be able to read and tamper with BIM data. The BIM-enabled collaboration requires the team members to share building information on the BIM platform (Ghaffarianhoseini *et al.*, 2017). However, the network adaptability of the BIM platform is imperfect to protect 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, Yiu and Amor, 2019).

- Data incompatibility

Data incompatibility is caused by different standards of technical parameters used to develop a BIM model (McGuire *et al.*, 2016). Specifically, the varieties of data format and level of detail used in a single project lead to interoperability problems (Nawari and Alsaffar, 2015), which may be caused by either semantics or software.

- Data integrity

Data integrity might be affected when entering and extracting information to the BIM environment (Liu, van Nederveen and Hertogh, 2017). For example, some building information could not be recorded into the BIM model because of the limited support provided by the BIM platform for that kind of information – i.e., some information may have to be represented in parts. Besides, the loss of building information during data format conversion can also affect the integrity of the data.

- Repetitive tasks

Repetitive tasks often occur when there are different stakeholders operating in the same BIM environment, such as when the BIM model is used 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, Kwak and Suk, 2016).

- Data non-traceability

The designer is only responsible for the BIM model before the construction stage, while they have no responsibility or obligation to modify the design model after the design stage (Liu, van Nederveen and Hertogh, 2017).

- Responsibility assignment

It's a tricky problem to arrange responsibility assignments on a BIM project because the idea of high integration in BIM conflicts with the highly autonomous practices of construction suppliers (Liu, van Nederveen and Hertogh, 2017). Some BIM project owners rely excessively on third parties to tackle the complicated responsibility assignment process (Olawumi and Chan, 2019).

- The information exchange process

The information exchange process in BIM has some flaws when collaborating with a third party or in cross-professional design (Liu, van Nederveen and Hertogh, 2017). Specifically, there is no clear specification about the level of detail in most shared BIM models (Redmond *et al.*, 2012), which leads to collaboration barriers between different stakeholders. This is also a barrier to the implementation of BIM.

- Data unreliability

The accuracy of the BIM data might not be sufficient to support collaboration between different stakeholders. Protecting digital property rights by sacrificing data accuracy is a common approach in most industries (Nawari and Ravindran, 2019), however, it might bring high project risks in the construction (Ghaffarianhoseini *et al.*, 2017).

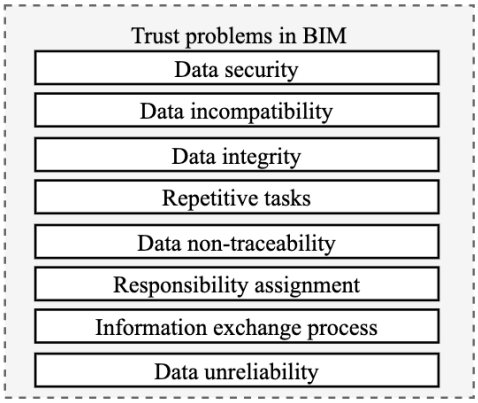


*Figure 1. Trust problems in BIM (adopted by the author)*

The above-discussed trust issues in BIM-enabled collaboration are summarised in Figure 1. As there is little research on trust in BIM-enabled collaboration, the trust problems listed above can be assumed to be incomplete. Next, through a critical discussion of the existing work on trust in psychology, economics, construction and virtual collaboration, this paper will inquire into the meaning and dimensions of trust in BIM-enabled collaboration.

## Theoretical framework of trust

Putnam (1993) defined trust as a key requirement for collaborative activities, which are underpinned by the social communication of people. Similarly, trust was regarded as expectations that are built on common standards within a community (Fukuyama, 1996).

The notion of trust has been widely discussed in psychology and economics (Guo and Chen, 2020). There are two different views on the nature of trust as proposed in psychology and economics (Laan *et al.*, 2011). Whether trust is calculable or not is the main difference between the definitions in psychology and economics (Kramer, 1999; Nooteboom, 2002; Rousseau *et al.*, 1998). Hence, in the following, these two distinct views of trust will be reviewed alongside t the extant literature on trust in construction.

## The concept of trust in psychology

From a psychological point of view, trust is defined as a state of mind facing others' attention and actions (Rousseau *et al.*, 1998). More specifically, Edmondson (1999) claimed that trust is the expectation that the future actions of others will benefit one's interests. Similarly, Fukuyama (1996) claimed that trust is the expectation of the community members, arising "within a community of regular, honest, and cooperative behaviour". It is built on commonly shared norms. After reviewing the definition of trust, Sahay (2003) concluded that trust means a non-negative expectation about the outcomes received from others' actions.

The above definitions refer to trust as a belief, but none of them explains specifically what dimensions trust consists of. There are several different views on the dimensions of trust in psychology. The current mainstream dimensions of trust originate from the two sources of trust first proposed by (Johnson-George and Swap, 1982): *Emotional Trust* and *Reliableness*. Since then, a certain level of agreement has been achieved in terms of the division of the dimensions of trust. According to this, trust consists of affective trust and cognitive trust (Johnson-George and Swap, 1982; McAllister, 1995; Moorman, Zaltman and Deshpande, 1992). Affective trust is the confidence between partners generated by the level of care of the partner (Johnson-George and Swap, 1982). Cognitive trust describes the confidence that is built in the competence and reliability of the other(s) (Moorman, Zaltman and Deshpande, 1992).

After the trust was divided into cognitive and affective trust, Lewis and Weigert (1985) added a third dimension of trust – behaviour trust. They argued that behaviour trust is the corresponding action that reflects the state of affective trust and cognitive trust. Since then, these three dimensions of trust have been widely agreed upon. These three dimensions are further explained below.

**Cognitive trust:** It is the confidence of put in the competence and reliability of the other(s) (Johnson and Grayson, 2005). It stems from accumulated knowledge. This means that it allows people to make predictions about the likelihood of a partner fulfilling its obligations with a degree of confidence. It is a cognitive process that distinguishes between trustworthy, untrustworthy, and unknown people and institutions. Trust involves a degree of familiarity with the object of trust that lies somewhere between complete knowledge and complete ignorance (Lewis and Weigert, 1985). Specifically, if someone is omniscient, this person could act without hesitation because the outcome is certain. By contrast, there is no trust for someone who is completely ignorant as the outcome of the action in such a case is unpredictable.

**Affective trust:** Johnson and Grayson (2005) suggest that affective trust is confidence based on feelings arising from the partner's care and concern. This affective component of trust includes the emotional bonds between all those involved in the relationship (Lewis and Weigert, 1985). The sociological basis of trust is also based on an emotional foundation. This affective trust complements the cognitive foundation (Johnson and Grayson, 2005). They argue that affective trust and cognitive trust interact with each other. The emotional content of trust helps to build and maintain cognitive trust. However, the nature of affective trust is based on emotional attachment to partners. As the emotional connection become deeper, the trust may go beyond what could be justified by knowledge. This is the reason why trust is not calculable in psychology (Johnson and Grayson, 2005).

**Behaviour trust:** The practical significance of trust lies in the social action that it underpins. Behavioural trust is expressed in risky courses of action based on the expectation that all those involved in the action will act with due diligence (Barber, 1983). Behavioural trust is interrelated with cognitive trust and affective trust. Behavioural displays that imply trust help to build the cognitive platform of trust (Luhmann, 2018). Behaviours that imply trust help to build or strengthen trusting emotions, because positive emotions circulate among those who express trust in behavioural ways, while negative emotions arise between those who betray or distrust each other.

There is another view that comes close to this third dimension of trust in psychology which is put forward by Wong *et al.* (2008), who focused on systems in their research instead of people. They claim that trust consists of three dimensions: cognitive-based trust (derived from information sharing and knowledge), affect-based trust, and system-based trust (derived from communication systems and flows). However, as communication systems and processes are behaviours that arise from human operating systems, arguably system-based trust can be assumed to be an expression of behaviour trust.

Ultimately, cognitive trust provides the basis for affective trust, which precedes the development of affective trust (Lewis and Weigert, 1985). However, as affective trust deepens, a reverse causal relationship between the trust dimensions becomes possible (McAllister, 1995). For example, with high affective trust, people may ignore negative facts and choose to trust others blindly. Besides, affective trust is intrinsically motivated to generate behaviour (Rempel, Holmes and Zanna, 1985). In other words, emotional communication is the bond that creates behavioural trust (Johnson and Grayson, 2005).

When analysing the trust, the three dimensions need to be integrated and analysed together, because these dimensions are interpenetrating and mutually supportive. The "trust" is not complete unless the three dimensions are regarded as a whole. In sum, in psychology, it is widely recognised that trust includes ***cognitive trust, affective trust,*** and ***behavioural trust*** (Johnson and Grayson, 2005; Luhmann, 2018).

## The concept of trust in economics

As mentioned above, the major difference between the definitions of trust in economics and psychology is whether trust is calculable or not. From the economic perspective, trust is calculable. A discussion of the dimensions of trust in this discipline will necessarily refer to calculative trust.

Calculative trust describes a rational choice perspective (Kadefors, 2004). Trust occurs when the trusting party

believes that the trustee intends to perform an action that is beneficial to the trusting party (Lee *et al.*, 2020). From this perspective, calculative trust is like the cognitive trust mentioned in psychology. But calculative trust in economics is a calculative process. Organisations or individuals calculate the costs or rewards of another party cheating or maintaining a relationship (Dasgupta, 1988; Williamson, 1993). Individuals are driven by their economic interests, while calculative trust in organisations is usually associated with financial incentives or contractual default clauses. References, certificates, diplomas and other information that convey the competence of potential partners may also influence calculative trust. In other words, calculative trust arises from the positive and negative consequences predicted by the parties involved in the collaboration (Williamson, 1993).

Apart from calculative trust, a second recognised dimension of trust is relational trust. Relational trust was first proposed by Rousseau *et al.* (1998) based on Williamson's study (Williamson, 1993). Subsequently, several studies have identified the second dimension of trust as relational trust (Kadefors, 2004; Lee *et al.*, 2020). Relational trust is developed over time between individuals who interact repeatedly (Kadefors, 2004). In other words, relational trust develops through reciprocity and socio-emotional exchanges, which require a higher level of confidence in the partner (Lee *et al.*, 2020). Through this relationship, the parties involved have access to direct, personal experiences and information. This information forms the basis of trust. And emotions and personal attachments influence this relationship. There are psychological and social risks in addition to the trusting relationship which contains strong feelings and can entail financial risks. For instance, Jiang, Lu and Le (2016) show that relational trust has a more significant impact on project performance than calculative trust. Appropriate contractual controls and contingency adaptability give parties more confidence in sharing information because common interests are protected, and uncertainty is reduced.

Views on the final dimension of trust in the economics school have not been as uniform as the first two dimensions of trust. Williamson (1993) claimed that the third dimension of trust is legal trust. However, Rousseau *et al.* (1998) argue that it should be institutional trust. This study follows Rousseau *et al.*'s study that the third dimension of trust is institutional trust as this seems to be the prominent dimension used most recently (Lee *et al.*, 2020). Besides, at the societal level, protecting individual rights and property by legal systems could be regarded as institutional trust (Fukuyama, 1996).

Institutional trust can provide support for calculative and relational trust, such as sustaining trust behaviour and taking risks (Gulati, 1995; Sitkin, 1995). These supports can show at the organisational level, or the societal level. At the organisational level, the institutional trust could be seen from a culture of teamwork (Miles and Creed, 1995).

In sum, in economics, trust is seen as involving ***calculative trust, relational trust,*** and ***institutional trust.***

**The concept of trust in construction research**

After reviewing the concept of trust in psychology and economics, this section focuses on trust as it is discussed in construction research.

The theory and dimensions of trust in construction research are not identical to other contexts due to the widespread uncertainty of ad-hoc collaboration and the complexity of construction projects (Wu *et al.*, 2020). However, construction projects are made up of a series of human collaborations and economic transactions (Guo and Chen, 2020). Therefore, arguably, the definition of trust in the construction industry needs to draw on both psychology and economics.

The dimensions of trust in the construction industry are not widely discussed in the existing literature. Therefore there is not a widely accepted definition of trust, neither there is any consensus on the relevant dimensions of trust. Manu (2014) classified trust in the construction industry into three categories: relationship, competence and system. Olatunji and Akanmu (2014) argued that trust includes cognitive-based trust, affect-based trust, calculus-based trust, difference-based trust, and institution-based trust. Qian and Papadonikolaki (2020) claimed that trust is classified as system-based trust, cognition-based trust, and relation-based trust. However, even though the above three studies used different terms to describe trust dimensions, these dimensions variously overlap with the dimensions of trust in psychology and economics, as well as with each other, to different extents.

Besides, when researching trust problems, in addition to considering the dimensions of trust, there is also a consideration of a variety of trust relationships between individuals, between organisations, or between individuals and organisations (Panteli and Sockalingam, 2005). For example, Khalfan, McDermott and Swan (2007) used a case study to analyse the interpersonal, inter-organisational, and project-related factors that influence developing trust in the Northwest of England construction industry. Similarly, Morgan Tuuli and Rowlinson (2010) summarised the antecedents of constructing trust at the individual level, team level, organisational level and project level. These studies highlight the vital factors which influence the development of trust might be different when dealing with different units of analysis (such as between individuals, between organisations, or between individuals and organisations).

Overall, although trust is widely recognised as a key requirement in construction research and practice, the theoretical development of the concept has rather been limited and dispersed. The different dimensions and levels of analysis adopted by various conceptual works resulted in the lack of a consistent theoretical framework of trust in construction.

**The concept of trust in virtual collaboration relationship research**

Before the discussion of the trust dimensions relevant to BIM-enabled collaboration, this section will touch upon the literature on trust in virtual collaboration relationships

(VCR). Although little research explicitly studied trust in BIM-enabled collaboration, there has been some valuable research on building trust in VCR, which is similar to building trust in BIM-enabled collaboration. This means that factors affecting trust in VCR are relevant to the trust problems in BIM-enabled collaboration, making VCR a relevant area of research when developing a conceptual understanding of trust in BIM-enabled collaboration. This section presents two studies on the development of trust in a BIM-like environment (virtual collaboration relationship), which discuss the antecedents as well as the consequences of developing trust from different aspects.

Building trust among all stakeholders in the construction industry is difficult because the supply chain in construction is highly fragmented. This is a similar problem of building trust and collaboration in a virtual team. Gardner, Kil and van Dam (2020) claimed that early trust in a virtual team is built based on: (1) cognitive trust such as personal experience, stereotypes, and reputation; (2) institution-based trust such as effective communication and contracts; and (3) disposition to trust such as willingness to depend on others and a basic faith in humanity. They discussed and concluded that cognitive trust and disposition trust may influence institution-based trust and argued that these three factors would help to develop the early trust, which is the foundation of late trust, as shown in Figure 2.

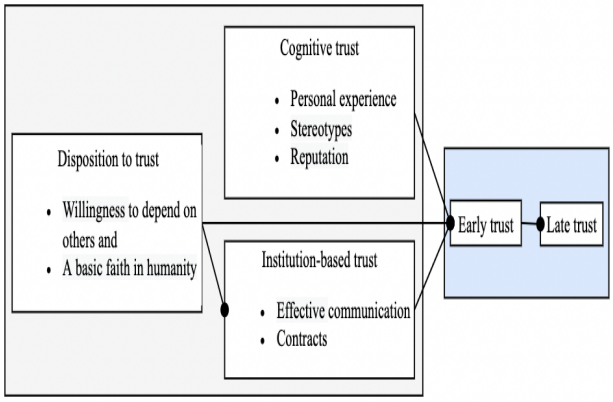


*Figure 2. Trust development on a virtual team (Gardner, Kil and van Dam, 2020)*

In another study about the relationship between interpersonal trust and virtual collaboration, Paul and McDaniel (2004) identified the types of interpersonal trust (calculative trust, competence trust, and relational trust) as well as the interrelationships between these different types of interpersonal trust. Specifically, calculative trust contains commitment and contract. Competence trust consists of the capability of an organization and the skills of a person. Relational trust includes friendship, shared identity, goodwill, and common values, as shown in Figure 3. According to this, calculative trust develops early trust. Further, with the combination of calculative trust and competence trust, an early trust may evolve into a deeper level of trust. However, relational trust is more influential in deeper and long-term trust relationships.

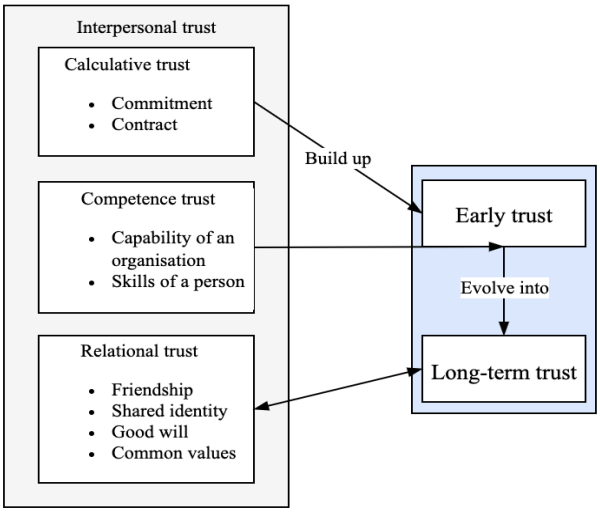


*Figure 3. Content of interpersonal trust and relationship among interpersonal trust and development of trust (Paul and McDaniel, 2004)*

Although they highlight different dimensions and interactions between these dimensions, a common aspect of these two studies is the emphasis on the interdependencies between the different dimensions of trust. Thus, these two studies imply that the interdependencies between different trust dimensions are a key concern when dealing with the concept of trust in virtual collaboration.

**Discussion: towards a theoretical framework of trust in BIM-enabled collaboration**

The theoretical foundations of trust are well established in psychology and economics while little research explored the trust framework in a BIM environment. BIM projects consist of people, a series of team activities and a series of economic transactions. Hence, it can be argued that it is appropriate to combine the concepts of trust from psychology and economics when studying trust in BIM-enabled collaboration. Therefore, to better understand trust in BIM-enabled collaboration, further research needs to consider the six dimensions from psychology and economics: ***cognitive trust, affective trust, behaviour trust, calculative trust, relational trust,*** and ***institutional trust***.

Besides, based on the studies on trust in VCR, it becomes clear that it is essential to pay attention to the relationships between different trust dimensions and early trust (or long-term trust). Additionally, when dealing with the concept of trust, there is a need to consider what the principal unit of analysis is (e.g., individuals, organisations etc.). For these reasons, future studies of trust in BIM-enabled collaboration should carefully consider the relevant unit of analysis as well as the interdependencies between the dimensions of trust, when building theory.

## 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 reviewed the trust literature in psychology, economics, construction and virtual collaboration, to discuss the meaning and dimensions of trust in BIM-enabled collaboration. It is concluded that the trust dimensions in psychology and economics can be a useful starting point for building a theoretical framework of trust in BIM-enabled collaboration. Further empirical research is needed to explore and validate the dimensions of trust employed in psychology and economics in BIM-enabled collaboration. Such an exploration will also need to account for the interrelationships between the different dimensions of trust as well as the different units of analysis relevant to trust in BIM-enabled collaboration (e.g., individual, organisational etc.).

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