Effect between Trust in Communication Technology and Interorganizational Trust in BIM-Enabled Projects

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Abstract: Building information modeling (BIM) and its associated digital tools have been widely adopted in designing, constructing, and operating infrastructures, particularly during the COVID-19 pandemic. However, the influence of these communication technologies on the interorganizational trust among project team members is unclear. In this study, BIM and its communication tools were conceptualized based on the perception of trust in communication technology to examine their influence on interorganizational trust. The effect of trust in communication technology on interorganizational trust was investigated through the mediation of obligatory cooperation and voluntary cooperation. In addition, partial least squares structural equation modeling was used to explore and predict the causal relationships of the model. The results show that trust in communication technology has no direct effect on interorganizational trust, but it positively affects their relationship via the mediation of obligatory cooperation. In comparison, trust in communication technology significantly impacts voluntary cooperation, which does not considerably influence interorganizational trust. Lastly, the findings of this study contribute new knowledge to trust theories for construction teams that use communication technologies to collaborate in BIM-enabled projects and provide an explanation on the development of trust by communication technologies through improvement of the interorganizational trust in BIM-enabled projects.

Keywords: communication technology, trust, building information modeling, partial least squares structural equation modeling, interorganizational trust, cooperation

Introduction

In recent years, various communication technologies have been increasingly used to enhance project performance in the project design, construction, and operation phases. Particularly, building information modeling (BIM) and its relevant communication tools, including virtual meeting tools, messaging applications, e-mails, and calls, are electronic media that offer alternative technical environments through operating systems, software, servers, and services without regard to geographic location (Chen et. al., 2016). These impact the manner of sharing information between team members and may result in improved collaborations. A survey conducted among 800 global human resource executives revealed that 88% of firms and institutions have either encouraged or required teleworking during the COVID-19 pandemic (Gartner, 2020). Most importantly, it is necessary for most construction professionals that could not work in project offices to effectively collaborate with other team members using available communication tools. BIM is not only a central depository platform to collect project information virtually, but it shows great potential in transforming project organizations and management practices (Du et. al., 2020). The deployment of BIM also prompts the use of other communication tools as it allows integration of other services and tools (Lu et. al., 2015), and BIM-associated communication technologies are often utilized to discuss BIM-related matters, which rely on the information produced from the BIM platform. Therefore, the study of communication technologies should include BIM and its associated communication technologies as the main tool. The dynamic development of these technologies in the construction industry and growing human dependency on them has gained the interest of industry researchers to uncover their functionality and uses (Krot and Lewicka, 2016). It was found that trust in communication technology of BIM-enabled projects is important in promoting effective BIM governance (Alreshidi et al., 2017), but the concept remains unclear.

Trust in communication technology refers to the faith of humans in the usage of technology (Ejdys, 2018). The first existing theory related to trust in communication technology is the media synchronicity theory (Dennis et. al., 2008), which suggests that communication technology can be placed along a continuum of low-to-high synchronicity based on several factors (e.g., transmission velocity, rehearsability, and reprocessability). Technologies that exhibit high synchronicity can build higher levels of trust because they can facilitate the convergence of meaning, which is essential for quickly moving beyond swift trust to deeper forms of trust (Dorairaj et al., 2010). This is because initial swift trust judgments give way to the verification and perceptions of shared purposes (Dennis et al., 2008). In BIM-enabled projects, the use of communication tools which is explained by the media synchronicity theory, a high level of synchronicity could improve trust among team members to promote knowledge sharing, even though construction project team members are unfamiliar with each other at the start of a project (Ma et al., 2021). The next theory, which is related to technology trust, is the technology acceptance model, which suggests that the main factors that influence the use of technology are perceived usefulness and ease of use (Davies, 1989; Venkatesh and Davis, 2000).

Extending from the technology acceptance model, it is observed that the perceived usefulness and ease of use of BIM are influenced by the calculative judgment of the project participants in assessing the time and cost spent in order to exchange the benefits of using the technologies. As such, trust in communication technology should be viewed from the perspective of transaction cost economics (TCE), which is centered on achieving economic efficiency through minimizing transaction costs (Williamson, 1993). Transaction costs are all expenses incurred in a transaction with another firm, including costs of developing and maintaining relationships, monitoring exchange behavior, and guarding against opportunism (Williamson, 1985; Tang et al., 2020). A previous TCE research proposed that knowledge misappropriation and opportunism have significant implications to firm transaction choices (Gulati and Sign, 1998). In the context of this study, trust in communication technology of BIM is obtained when team members believe that the benefits of using a particular technology outweigh the calculated costs or risks. Besides, BIM implementation should also be viewed from the sociotechnical viewpoint, which emphasizes on maintaining the system alignment between technical processes and multiple interest groups (Sackey et. al., 2015). Therefore, another principle that could frame the trust in communication technology of BIM is the social exchange theory (SET). SET emphasizes on social connections to safeguard against risks (Blau, 1964; Zhong et al., 2017) and focuses on the reciprocity doctrine, i.e., that a person is willing to work cooperatively with others expecting the rewards of the relationship. Although trust is not a result of contracts or hostage as of the opinion of social exchange theorists, the common attribute of the principles of TCE and SET is that they use cost-benefit analysis to influence the calculative judgment of BIM-enabled project participants in determining their next course of action. The literature of social exchange proposes that constant collaboration to exchange project information could increase the level of reputational source of trust and shared values among project participants (Ybarra and Wiersema, 1999). As a result, in this study, trust in communication technology of BIM is defined as the belief of the outcomes generated from the physical attributes and intangible benefits of BIM and its communication technologies with an acceptance of the possible losses due to disruption that the use of these technologies may bring. There are two innovation prcesses related to the use of BIM and its asssociated communication technology, namely, adoption and implementation (He et al, 2017). Trust in the physical attributes of BIM and its associated communication technologies may have strong influence in the stage of adoption; however, during BIM implementation, trust in the intangible benefits of BIM and its associated communication technologies that are brought from the collaboration are paramount to unleashing the full benefits of BIM. Trust in communication technology should be viewed as the belief of team members in the BIM attributes, which are (1) physical attributes that lead team members to use BIM and its communication tools, such as the perceived usefulness and ease of use (Venkatesh and Davis, 2000), and (2) intangible attributes that impact positive human interaction in terms of knowledge sharing and collaboration.

Prior studies have demonstrated the importance of using BIM to improve project performance via interorganizational trust (Zhang et al. 2016; Lee et al., 2018; Robson et al., 2019; Lee et al., 2020). However, the influence of trust in communication technology on interorganizational trust among firms involved in BIM-enabled projects is equivocal. Identifying the specific conditions that give rise to trust in an interorganizational relationship is essential for determining the variables in structural conditions (Khalid and Ali, 2017; Lioukas and Reuer, 2015). The frequent interactions that develop reciprocity among project participants are the results of BIM processes, which are perceived as a technical change and key to these conditions. This change requires alignment among people, structures, processes, and cultures of the organizations involved in the projects (Tulenheimo, 2015). One of the possible variables that connect trust in communication technology of BIM and interorganizational trust is the cooperative behavior. In this regard, cooperative behaviors, which refer to the aligned actions taken by the partners to achieve the collectively envisioned goal (Castañer and Oliveira, 2020), developed by project team members need to be considered. The central framing of cooperative behaviors is TCE and SET (Granovetter, 1991; Williamson, 1985). Several researchers define cooperation as the willingness to get involved or expect non-opportunistic behaviors (Parkhe, 1993; Das and Teng, 1998). Meanwhile, others define it as the willingness to maximize a common goal or develop a mutually beneficial relationship (Quanji et al., 2017; Wang et al., 2016). Cooperative behaviors can be classified as obligatory and voluntary behaviors; obligatory behaviors result from following the mandatory rules and role descriptions to achieve a minimum level of behavior, while voluntary behaviors are impulsive behaviors beyond the stipulated role descriptions. For instance, contractors may propose constructive suggestions to improve the design and cost of projects that are not stated in the contract (Wang et al., 2017). TCE emphasizes the choice of appropriate governance, such as detailed contracts, to mitigate transaction concerns and hazards (Williamson, 1985). Conversely, SET proposes that reciprocated relationships among team members are enhanced through repeated interactions of team members who believe that other team members will keep their promises, act in a fair and predictable manner, and inform the team members if incidents occur. Interorganizational trust, on the other hand, is often studied in terms of its effect on project success by developing high-performance teams and improving efficiency (Cerić et al., 2021). It is the belief held by a firm towards another firm (Lui & Ngo, 2005). One notable view is that repeated interactions generate familiarity (Gulati and Singh, 1998; Lee and Chong, 2021), increasing the partners' belief in competency and goodwill (Saparito et al., 2004; Lui and Ngo, 2004).

The aforementioned discussions suggest that trust in communication technology could influence obligatory cooperation and voluntary cooperation to impact positive interorganizational trust via TCE and SET, respectively. From the perspective of BIM-enabled projects, this study asserted that the deployment of BIM is the result of the project participants' trust at the early stage of project implementation. However, its use requires a high cost of exchange, which needs to be governed by the contractual mechanisms to stimulate the obligatory cooperation for safeguarding the contracting parties' interests. Voluntary cooperation is established from the reciprocal relationship developed based on the frequent information exchange of BIM. Both cooperative behaviors create a familiarity that leads to better interorganizational trust. Moreover, geographical constraints and technological mediation create challenges to effective work coordination and cooperative decision-making in virtual construction teams, particularly during pandemics (Bergiel et al., 2008; Iorio and Taylor, 2015). A higher level of trust should be established in a new system to ensure commercial success (Matthews et al, 2017). To date, there are no empirical studies that have investigated the causal effects of trust in communication technologies on interorganizational trust via cooperation, and no studies have conceptualized the definition of trust in communication technology for BIM-enabled projects. Determining the causal effect of these relationships can be beneficial on a wider scale because managers can have a better understanding of the effective mechanisms used to improve project performance, especially in the absence of face-to-face meetings and the fact that teleworking will be a permanent attribute of a post-pandemic generation (Lodovici et. al., 2021). Moreover, the number of construction firms that use the information and digital technologies to enhance business practices has increased significantly after the pandemic (CCIA, 2020). Therefore, the results of this study would render a significant collaborative approach revolving around communication technologies and trust theories for improved communication and collaboration in BIM-enabled projects.

The first section of this paper introduces the background and problem statements of this study. The remainder of this paper is organized as follows: the second section covers the hypothesis development; the third and fourth sections present the research methodology, results, and data analysis; and the last two sections focus on the discussion and conclusions.

Hypotheses Development

Trust in communication technology indicators includes physical and invisible attributes derived from collaborations. In particular, these physical characteristics derived from the technology acceptance model (perceived usefulness and ease of use) are predictable, functionable, robust, secure, and user-friendly; they also contain rich information models and share information in the Common Data Environment (CDE). This influenced the calculative judgment of project participants towards the use of BIM, owing to its potential advantages that can result in an increase in the confidence in its usage. Moreover, BIM is viewed as a sociotechnical system developed from the Leavitt sociotechnical systems model (Leavitt, 1964), highlighting the importance of understanding the interrelations of the elements that operate in a working system. The model shows a subtle interplay between several drivers that cause the disruption, maintenance, and stability of the work system, including technology, actors, structures, and tasks (Sackey et al., 2015). In this regard, trust in communication technology also influences the social exchange of project team members through collaboration attributes, such as the BIM workflow, which provides a better understanding of the members' responsibilities and helps the development of mutual understanding among team members.

There is no specific uni-dimensional construct that could represent interorganizational trust as scholars defined it based on the context of their studies (Zaheer and Harris, 2006). Nevertheless, it is observed that most of the scholars define interorganizational trust as the willingness to be vulnerable while expecting that partners will act reliably (Zaheer et al., 1998; Dyer and Chu, 2000; Jap and Anderson, 2003; Li et al., 2018; Akrout and La Rocca, 2019). Interorganizational trust reduces the control efforts of project participants and develops team spirit (Girmscheid and Brockmann, 2010). To determine the appropriate construct that represents interorganizational trust in the context of this study, the outcome of interorganizational trust should be examined from the project participants' view on trust. At the project level, interorganizational trust is the positive expectation of a project participant towards another project participant and the perceived ability to fulfill these expectations in the construction industry (Zhang et al. 2016). As such, it is rational to use constructs derived from competence trust (i.e., trust in the partners' ability to fulfill their roles) and goodwill trust (i.e., trust in the partners' willingness to perform their roles) to sustain interorganizational relationships and develop interorganizational trust (Lui and Ngo, 2004).

Competence trust is defined as the belief of one party in the ability of the other party to perform the work required in a transaction (Pinto et. al., 2009). Although competence trust exists before the commencement of a project, as the BIM progresses during the project, competence trust evolves and is gained through the repeated interactions of project participants (Yan and Zhang, 2020). Therefore, the competence of project participants is essential to ensuring smooth BIM-enabled project delivery and preventing the loss of investment of project participants in the projects. The reciprocal relationship through communication technology, which can be considered as a sociotechnical system, would develop goodwill trust among team members to perform their voluntary roles. Specifically, team members who are competent in dealing with BIM, which requires users to have specialized skills in designing, implementing, and operating this system, gain trust from other team members to perform their roles using their qualifications and resources and building their professional rapport among members during a collaboration. The SET theory studies the social behavior of team members during a social exchange and promotes more interaction in return to expectations, intensifying the team members' commitment to keep their promises, act fairly and predictably, and inform the other team members in case of incidents. A high degree of trust leads to open communication, which facilitates a better relationship among team members and allows members to put aside their personal ego for the team's benefit (Lewicki et al., 2006). Moreover, the chance of withdrawal is reduced when team members have an increasing level of goodwill trust (Gűth et al., 2008). The partners' incentive can be comprehended (Mayer and Argyres 2004), and goodwill trust of the other party through an accumulation of cooperation can help reduce transaction costs (Chen et al., 2017).

The governance system that provides appropriate details and protections should be coupled with goodwill to stabilize the circumstance of being exploited (Lui, 2009). Although it was previously mentioned that goodwill trust will be developed through repeated interactions, it is important to understand when the goodwill trust commences. Goodwill trust is an expectation of one party that his counterparty intends to fulfill his role in the relationship (Noteboom, 1996). This type of trust enables cooperation resulting in less worry for the counterparty about the potential project issues and increases confidence that the counterparty is engaging in a reciprocally mutual interest (Das and Teng, 2001; Das and Teng 1998). In construction projects, competence trust and goodwill trust co-exist when a contract is formed. There may also be a hierarchy of trust moving from competence trust to goodwill trust (Fong and Lung, 2007). Goodwill trust evolves owing to repeated interactions, which may or may not be derived from competence trust, but both competence trust and goodwill trust appear beforehand at the beginning of the project and continue to develop throughout the end of the project. Hence, the development of trust within a project context via this two-dimensional trust is essential to be viewed as a unidimensional trust in the interorganizational project setting. This unidimensional trust is inferred as interorganizational trust in this study. From the discussions above, it is inferred that trust in communication technology then influences interorganizational trust via the belief of project participants in the competence of other project participants and reciprocal relationships developed among each other in delivering BIM. Thus, this study posits the following hypothesis:

H1 *Trust in communication technology has a positive effect on interorganizational trust.*

Obligatory cooperation mediates trust in communication technology and interorganizational trust

From the perspective of TCE, behavioral uncertainty is the result of the ambiguity of cooperative members' behaviors (Zhou and Poppo, 2010). The information of construction projects is typically incomplete and asymmetric, which complicates the transaction environment and increases risk (Wang et. al., 2020). Owing to bounded rationality, people often cannot predict all risks before a transaction commences (Zhang and Qian, 2017; Yao et. al., 2019). Contracts are effective mechanisms to attenuate opportunism, which is a result of asset specificity and uncertainty (Williamson, 1985). The importance of ex-post trust (trust after commencement of a construction project) is useful for reducing the transaction cost of post-contract and for promoting cooperation (Yan and Zhang, 2020). The trust in communication technology gained from the use of BIM may influence the obligatory cooperative behaviors of team members via ex-post trust, as delivering BIM is normally part of the requirements of a project, which stipulate the obligations that parties should comply with in implementing BIM. In this study, we adopted the concept of obligatory cooperation investigated by Quanji et al. (2017), in which the team members performed their described roles and complied with the expected tasks, rules, and regulations to meet the performance expectations. Throughout the obligatory cooperation, which requires repeated interactions, project team members become more familiar with each other; thereby increasing their faith in the competency of other project team members and believe in their willingness to keep their promises (Chen et al., 2017), act predictably and fairly in negotiations, (Lui and Ngo, 2004) and inform the team members and react immediately when an incident occurs (Jiang et al., 2016). Thus, it is posited that:

H2 *Obligatory cooperation mediates trust in communication technology and interorganizational trust.*

Voluntary cooperation mediates trust in communication technology and interorganizational trust

Cooperation among project participants is essential for construction projects. Moreover, it is impossible to set certain definitions on extensive roles in construction contracts because of the complexity and flexibility encountered in the projects. Thus, terms such as "best endeavors" and "good practices" are implicitly included in ambiguous contracts, making some team members only comply with the minimum requirements (Quanji et al., 2017). Actions from team members who are willing to go beyond minimum practices by providing better solutions to improve performance are considered voluntary cooperative behaviors, which also include the behaviors of team members who are eager to follow project rules such as pilfering, health, and safety to ensure the success of the project despite these rules clearly defining the project (Anvuur and Kumarswamy 2012).

BIM stimulates collaboration among team members that develop voluntary behaviors in the project network. Organizations may not necessarily adopt safeguarding governance to prevent transaction hazards but to form alliances to mitigate risks (Lioukas et. al., 2016). According to SET, trust emerges through social interactions between exchange partners (Blau, 1964). Trust in communication technology, which develops from project collaboration, increases team members' voluntary cooperation to reduce risks and improve project performance. Team members are willing to provide innovative ideas to expand the project success rate, follow the policies, accept the decisions made by the owner, and comply with the owner's expectations (Quanji et al., 2017). When team members receive positive initiating action, such as communication about the mutual goals of BIM and acknowledgment of their contributions to BIM, they reciprocate the treatment with good behaviors or more positive returning responses, such as better cooperative behaviors, to influence competence and goodwill trust among team members (Cropanzano et al., 2017). To further illustrate the influence of voluntary behaviors on competence trust, voluntary cooperative behaviors that are developed from using BIM and its relevant communication technology help accomplish BIM tasks and resolve issues that are not addressed in contractual arrangements (Braun et. al., 2012). The competency demonstrated from these behaviors could further enhance the competence trust of project participants in their project team members. Hence, it is posited that:

H3 *Voluntary cooperation mediates trust in communication technology and interorganizational trust.*

Obligatory cooperation and voluntary cooperation mediate trust in communication technology and interorganizational trust

Trust in communication technology can impact interorganizational trust through multiple mediations via obligatory and voluntary cooperation. Obligatory cooperation can develop voluntary cooperation that improves interorganizational trust among team members based on SET. At the interorganizational level, firms would usually have inter-disciplinary teams working on BIM-enabled projects. The obligatory cooperation developed from BIM requirements would further accelerate voluntary cooperation among team members. Moreover, there are repeated reciprocal interactions owing to obligatory cooperation, which has been defined before the start of the project. Cooperative behaviors then impact interorganizational trust, which acts as a lubricant to complex and interlinked processes (Zaheer and Harris, 2006). Thus, this study hypothesizes the following:

H4: *Obligatory cooperation and voluntary cooperation mediate trust in communication technology and interorganizational trust.*

Conceptual Framework

Figure 1 shows the conceptual framework developed from the discussions above, and Table 1 presents the structural equation formula used to estimate the hypothesis. We assigned trust in communication technology as the independent variable, the voluntary and obligatory cooperation as the mediators, and interorganizational trust as the dependent variable. Hypothesis 1 can be calculated using the equation of direct effect (c), which is the path coefficient from trust in communication technology (TC) to interorganizational trust (IT), or total effect (c'), which represents the total value of the direct effect (c), H2, H3, and H4. Particularly, the equation obtained for H2 and H3 is derived from an indirect effect, indicating that these equations are calculated by multiplying the value of the path coefficient from the independent variable to the dependent variable. Moreover, the path coefficient value for H4, which involves multiple mediation variables, was obtained by multiplying 1a with 1c and 2b.

Research Methodology

Data collection

A list of constructs with their indicators, which are listed in Table 2, was developed based on the aforementioned hypotheses discussed in the previous section to test the hypothesis model. These constructs were obtained from the pre-existing measurements scale that had been recognized as the mature scale by many researchers in the built environment sector such as Lui and Ngo (2004), Jiang et al. (2016) and Chen et al. (2017). There exist two approaches to ensure the reliability and validity of measuring the constructs. The first approach is to obtain the indicators from existing studies. As trust in communication technology is newly introduced in this study, the indicators were extended from the technology acceptance model and were also included with the constructs relating to the belief in the intangible benefits obtained from the BIM workflow that could develop the reciprocal relationship. The second approach is to examine the measuring constructs through reliability and validity tests; these are explained in the data analysis method section below. To further ensure the validity of the measurement constructs, a pilot test was conducted with BIM practitioners before a survey questionnaire was released. The survey questionnaire, which is divided into two sections, included the first section that asked questions about the projects' and respondents' information, as shown in Table 3. Meanwhile, the second section required respondents to rate their agreement with the indicators using a five-point Likert scale ranging from strongly disagree (0) to strongly agree (5).

Sample Data

A total of 93 samples were collected from BIM-enabled projects in Malaysia, as per the funding requirement of the funding agency, the Ministry of Higher Education Malaysia, from August to December 2020. The respondents were asked to fill out the survey form based on the latest BIM-enabled project they were involved in. In the context of this study, we defined BIM as projects involving levels 0 to 3, as shown in Table 3. Level 3 is the highest level of BIM use. In this level, a unified model is stored in a central repository that all model contributors can access and modify, reducing the risk of information conflicts (Awwad et. al., 2020). Level 2 with 3D model collaboration through common file formats recorded the highest percentage (34%). In contrast, respondents who collaborated on Level 2 using 3D, 4D, 5D, and 6D models using standard file formats accounted for 19% of the total, which was the second-highest among all BIM levels. Lastly, only 3% of respondents selected Level 3. The respondents' primary roles were either contractors (34%) or architectural design consultants (20%). A noticeable characteristic was that the ages and years of work experience of respondents were below 40 years and 10 years, respectively, indicating the popularity of BIM in recent years.

Data Analysis Method

From the 93 samples that were collected, only 80 samples were used for analysis after assessing the straight-line pattern and outliers in the data. Post-hoc statistical power analysis was conducted to determine the effect size, and it was found that the power exceeded 0.8 with a sample size of 80, an R2 value of 0.55, and a significance level of 5%, suggesting that there was a greater chance of getting a statistically significant difference in this study (Cohen, 1992). Partial least squares structural equation modeling (PLS-SEM) was chosen to explore and predict the causal model as some constructs were newly generated and had not been examined in previous studies. The missing value recorded was less than 15%, which suggests a mean replacement in PLS-SEM and the missing completely at random (MCAR) test. The results showed that it was not statistically significant, suggesting that the data were not missing completely at random. Hair et al. (2017) suggested that skewed and high kurtosis data that exceed +1 and -1 were treated before conducting the PLS-SEM analysis.

The data were then analyzed using the PLS-SEM method, carrying out two steps of the analysis. The first analysis evaluated the measurement model while the second analysis evaluated the structural model. The measurement model developed was a reflective model, demonstrating causality flows from variables to indicators, and was assessed using internal consistency reliability, convergent validity, and discriminant validity. The validity of internal consistency among indicators of the constructs was assessed using the outer loadings of different indicators to investigate the reflective measurement model. The indicators are maintained if their outer loading value is above 0.70 but below 0.90. Moreover, average variance extracted (AVE) was used to assess the convergent validity, which is the extent to which a measure positively correlates with alternative measures of the same construct of indicators. Therefore, the AVE value of a construct should exceed 0.50, explaining more than half of the variance of its indicators. Indicators with outer loading values between 0.40 and 0.70 are removed if their deletion increases the composite reliability or AVE. The measurement model was then examined with the discriminant validity to identify whether a construct is unique and capture phenomena are not represented by other constructs in the model. The discriminant validity was examined using the Fornell-Larcker criterion, which was developed based on the logic that a construct shares more variance with its associated indicators than any other constructs. The heterotrait-monotrait ratio (HTMT) is claimed to be a more reliable method for assessing the discriminant validity because the Fornell-Larcker criterion cannot detect discriminant validity in some situations (Henseler et al., 2015). Moreover, HTMT values of all variables should be lower than 0.90 to assess the validity of the discriminant. The common method bias was examined using full collinearity assessment, whose variance inflation factor (VIF) values should be lower than 3.3 (Kock, 2015; Hair et al., 2017). The systematic bias was examined to investigate the possible influence of low and high levels of BIM use on trust in communication technology using one-way ANOVA analysis.

Table 3 and Fig. 1 show the formulas used to calculate the structural model. In addition, the structural model was evaluated using collinearity assessment to assess the significant effects of path coefficients of the causal model and examine each set of predictor constructs separately for each subpart of the structural model. In this case, the VIF value for each indicator was used. If the collinearity value was lower than 2.00 and more than 5.00, the construct was eliminated, merging predictors into a single construct and/or creating higher-order constructs to treat collinearity problems. The path coefficients were then assessed; estimated path coefficients close to 1 indicate strong positive relationships and are always statistically significant. The closer the estimated coefficients are to zero, the weaker are the connections. The accuracy of the structural model was assessed using the coefficient of determination (R^2 value) after determining the significance of path coefficients. The R^2 value ranges from 0 to 1, with higher levels indicating higher levels of predictive accuracy. In addition, the f^2 effect size was assessed, which can be estimated as small (0.02), medium (0.15), and large (0.35) (Cohen, 1998). Furthermore, Stone–Geisser's Q^2 value, which is an indicator of the predictive relevance of the model, was examined to evaluate the magnitude of the R^2 values as a criterion of predictive accuracy (Geisser, 1974; Stone, 1974). In the structural model, Q^2 values larger than zero for a particular reflective endogenous latent variable indicate the predictive relevance of path model for that specific construct. The effect size of the predictive relevance for the endogenous variable is measured through q^2.

Results and Data Analysis

Evaluation of the Measurement Model

The reflective model should be assessed using the three measurements discussed earlier. It was found that TC_1, TC_2, TC_3, TC_4, and TC_5 were removed because their outer loading value was lower than 0.70, indicating that they were not applicable in most respondents and/or were inconsistent with other indicators. This removal resulted in increased composite reliability or AVE. Table 4 shows that all AVE values of the constructs exceed 0.50, and the discriminant validity of the constructs is shown in Table 5. It is apparent that all constructs have HTMT values below 0.90, indicating that each construct is distinctive and captures phenomena that are not represented by any other construct in the model. All VIF values of the indicators are found to be below 3.3, which indicates that the model is not affected by common method bias. There is a very small systematic error found in TC_7 by comparing high and low levels of BIM use on the trust in communication technology, which corresponds to a significant statistical difference below 0.10.

Evaluation of Structural Model

On the other hand, the collinearity of constructs should be evaluated using the VIF to assess the structural model. VIF values greater than 5.00 represent critical levels of multicollinearity where the coefficients are poorly estimated and the p-values are questionable. All VIF values of the indicators are between 2.00 and 5.00, indicating that the coefficients are adequately calculated.

Table 6 shows that, although originally communication technology trust has no direct effect on interorganizational trust (H1, $\beta = 0.119$, $p > 0.1$), trust in communication technology has a positive effect on interorganizational trust through the mediation of interorganizational trust and cooperative behaviors ($\beta = 0.481$, $p \leq 0.01$). Next, there is a significant indirect effect of trust in communication technology on interorganizational trust through obligatory cooperation (H2, $\beta = 0.242$, $p < 0.05$) because of the significant direct effect found between trust in communication technology and obligatory cooperation ($\beta = 0.460$, $p < 0.01$), and between obligatory cooperation and interorganizational trust ($\beta = 0.527$, $p < 0.01$). However, there is no significant indirect effect of trust in communication technology on interorganizational trust through the mediation of voluntary cooperation (H3, $\beta = 0.04$, $p > 0.1$). Still, there is a significant positive direct effect of trust in communication technology on voluntary cooperation ($\beta = 0.24$, $p < 0.05$). There is also a significant effect of obligatory cooperation on voluntary cooperation ($\beta = 0.652$, $p < 0.01$), although there is no significant indirect effect of multiple mediations of obligatory cooperation and voluntary cooperation on the relationship between virtual technology trust and interorganizational trust (H4, $\beta = 0.05$, $p > 0.1$).

Then, the R^2 value of each construct was assessed after determining the significance of the path coefficients. Table 7 shows that R^2 values range from 0.228 to 0.641, suggesting a high level of predictive accuracy. In addition, Q^2 values are all larger than zero, indicating the predictive relevance of the path model for the constructs. Moreover, the effect sizes of f^2 and q^2 are presented in Table 8. The estimated effect sizes are small (0.02), medium (0.15), and large (0.35) (Cohen, 1988). There is at least a small effect size of endogenous variables, except for trust in communication technology, on interorganizational trust and of voluntary cooperation on interorganizational trust.

Discussions and Contributions

Making clear of the construct of trust in communication technology for BIM-enabled projects

Existing literature states that embedding trust in BIM technologies is a factor informing efficient BIM governance (Alreshidi et al., 2017), and some prior studies reported that the \challenges of promoting trust in BIM include data security and accessibility issues (Fan et al., 2018), model ownerships and copyrights (Dounas et al., 2021; Liu et al., 2017). However, previous studies do not clarify or contextualize the construct of trust in BIM and its associated communication technologies. The findings of the study show that the indicators that represent the construct of trust in communication technology of BIM-enabled projects are the beliefs of project participants on the fair design of BIM workflow (*TC_6*) and the BIM workflow, which promotes shared understanding (*TC_7*). The physical attributes of BIM-associated communication technologies (*TC_8 to TC_11*) could promote trust, but this is not the case in BIM physical attributes (*TC_1 to TC_5*). This suggests that the industry needs to put more effort to resolve concerns regarding the physical attributes raised by BIM stakeholders, such as making use of the BIM information-rich model to provide useful information across all project stages (Kensek, 2015), improving the robustness and processing time of the BIM model (Akinade et al., 2016), increasing the security access of common data environment, and clarifying the BIM workflow for better understanding of project participants' responsibilities (Fan et al., 2018). The findings also suggest that, besides using BIM tools to communicate the project information, project participants should also optimize its associated communication tools, such as virtual meeting tools, messaging apps, e-mails, and calls, to connect and share the project information as the beliefs of project participants on BIM-associated communicated tools are significant. The results of this study also indicate that the focus of improving trust in BIM should be placed in the BIM implementation stage, which involves the belief of its intangible benefits to promote knowledge sharing and collaboration via a BIM workflow that is fair and promotes shared understanding among project participants. This study contributes to the theory development of trust in communication technologies of BIM-enabled projects, which contextualizes the concept of communication technology trust that should be held by BIM-enabled project participants. The construct of trust in communication technology of BIM-enabled projects in the context of this study is developed from the theories of TCE and SET, which argue that trust is influenced by the calculative judgment of parties concerning the cost-benefit analysis of deploying the technologies and the reciprocal relationship developed from knowledge sharing and collaboration.

Trust in communication technology does not directly influence interorganizational trust

Prior studies show the influence of BIM on interorganizational trust through interaction between technology, people, processes (Liu et. al., 2017), prior ties (Lee et. al., 2021), and contract functions (Lee et al., 2020); however, the influence of trust in BIM and its associated communication technologies on interorganizational trust remains unclear. Through the contextualization of trust in BIM, this study identifies that trust in communication technology does not directly influence interorganizational trust, but there exists an effective relationship between them via the mediation of cooperative behavior. This finding addresses the research question introduced herein and helps explain the antecedents that make these communication technologies improve interorganizational trust. From the perspective of practical implications, the mediating relationship provides a reference to project managers to use BIM effectively as a cooperative platform for improving interorganizational trust. Trust in BIM is achieved via a fair BIM workflow that promotes shared understanding and the physical attributes of BIM-associated communication technologies. Project owners or managers should act wisely when adopting BIM and its associated communication technologies as a platform for improving cooperative behaviors, which impact interorganizational trust among project participants. As cooperative behaviors resulting from trust in BIM are essential to developing interorganizational trust, project owners and managers should understand the effective means to enforce cooperative behaviors. These include making individual team members feel that they are essential parts of the project team and provide clear directives on the rules and tasks that team members should comply with in performing their work.

Obligatory cooperation mediates trust in communication technology and interorganizational trust

To date, there is no global measurement developed to differentiate the effects of BIM on a specific type of cooperative behavior (Wang et al., 2017). This study explains the impact of trust in communication technology on interorganizational trust via obligatory cooperation and empirically identifies that trust in communication technology developed from both BIM's physical and intangible attributes as a sociotechnical system influences obligatory cooperation via TCE. Mandatory requirements that develop obligatory cooperation are fundamental in maintaining interorganizational relationships based on the perspective of TCE (Das and Teng, 1996). Relational risk is a result of potential opportunism and manifests as non-cooperative behaviors. In the construction industry, monitoring project participants via adequate outcomes and behavioral contractual control may decrease the cost of hidden self-interest activities and limit opportunistic intentions to violate the provisions of contracts (Zhang et al., 2018). It also allows parties to better observe each other's behaviors, thus escalating trust-building and reciprocal forbearance (Luo, 2002). When the possibility of the perceived objective of a repeated transaction is high, project participants will care more about benefits from future cooperation. As a result, they will reduce current opportunism and complete stipulated tasks (Parkhe 1993), increasing obligatory cooperative behavior (Wang et al., 2016). From the perspective of practical implications, BIM requirements that are adequately set in the contracts for the outcome and behavioral control to enable better obligatory cooperative behaviors will reduce the likelihood of exchange hazards. Project participants should ensure that contract provisions that address BIM collaborative procedures are clearly and widely introduced in the contracts to allow better cooperation (Ragab and Marzouk, 2021). Project participants should focus on using contracts to codify BIM-related provisions and promote, plan, and manage collaboration to improve interorganizational trust instead of using safeguarding provisions excessively to protect their interest, which may hinder interorganizational relationships (Hurmerinta-Haanpaa and Viding, 2019).

Trust in communication technology influences voluntary cooperation significantly, but voluntary cooperation does not mediate the relationship between trust in communication technology and interorganizational trust significantly

The study reveals that trust developed from BIM and its relevant communication tools can directly influence voluntary cooperation. This is in line with the SET perspective that long-standing relationships can exist and earn a good reputation for future projects (Granovetter, 1985). Voluntary cooperative behaviors include carrying out extra task activities or helping others with task-related problems, which are not formally part of one's job role (Quanji et al., 2017). Trust in communication technology from team members could enable them to work beyond their responsibilities to achieve better project performance and provide innovative recommendations to improve project performance. However, voluntary cooperation does not sufficiently mediate the relationship between trust in communication technology and interorganizational trust because of the inherently fragmented practices that are not significantly influenced by voluntary cooperation among team members. Although voluntary cooperation would allow better construction practices that would ultimately help to improve project performance, more proactive efforts are required or initiated to influence the voluntary cooperation of team members who use BIM and communication tools. Contractual control, coordination, and adaptation positively influence voluntary cooperation (Quanji et al., 2017; Lee et al., 2020). As a result, a fair workflow of BIM practice that promotes shared understanding could influence cooperative behaviors to improve interorganizational trust. Therefore, managers should ensure fairness across the project lifecycle by, e.g., designing fair BIM procedures for decision-making, providing accuracy, trustfulness, and timeliness of the information shared, and communicating the BIM procedures with respect and dignity, to encourage voluntary cooperation (Shafi et al., 2021).

Conclusions

This study contributes to a better understanding of the existing trust theory by explaining the influence of trust developed from communication technologies, such as BIM and its associated digital communication tools, on interorganizational trust in BIM-enabled projects. This has been particularly important during the COVID-19 pandemic because teleworking has been globally implemented as most construction professionals and members cannot meet face-to-face. Moreover, obligatory cooperation is a vital mediator of trust in communication technology in improving interorganizational trust, whereas voluntary cooperation is positively influenced by communication technology trust and does not sufficiently impact interorganizational trust. While many BIM standards have been established, this study suggests that the construction industry should set up an understandable BIM execution plan that promotes better collaborative practices with clearer and fairer standards to achieve a mutual understanding among team members and effectuate the positive outcome of their collaboration. Additionally, it was identified that the current BIM collaboration in the construction industry is lacking in voluntary cooperation, affecting the interorganizational trust among team members. Various suggestions have been provided for the effective implementation of BIM, which resulted in improved interorganizational trust. However, this study has several limitations, including: (1) the existence of several variables, such as the level of effectiveness in communication and the extensiveness of shared information, that could influence trust in communication technology and impact interorganizational confidence; and (2) the lack of research on moderator variables that could accelerate the mediation relationship among trust in communication technology, obligatory cooperation, and interorganizational trust. Future research could examine the influence of these variables on the positive paths revealed in this study. It could also investigate related empirical studies for the impacts of various BIM usage levels, frequency of communications, and types of contracts on the path models.

Data Availability Statement

All data, models, and code generated or used during the study appear in the submitted article.

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Tables Captions

Table 1. Types of effects used to test the hypothesis

Table 2. Variables and indicators

Table 3. Basic information of respondents and projects

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Table 5. Heterotrait-Monotrait Ratio (HTMT) values

Table 6. Overall results of hypotheses testing

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Table 8. Effect size f^2 *and* q^2

Table 1. Types of effects used to test the hypothesis

Hypothesis	Type of effect	Equation
H1 TC > IT	Direct effect	c or
	Total effect	c' = c + H2 + H3 + H4
H2 TC > OC > IT	Indirect effect	H2 = 1a*1b
H3 TC > VC > IT	Indirect effect	H3 = 2a*2b
H4 TC > OC >VC > IT	Indirect effect	H4 = 1a*1c*2b

*Note: * and + indicate multiplication and addition, respectively*

Table 2. Variables and indicators

Constructs	Indicators	References
Trust in communication technology (*TC*)	1. We believed the predictability of BIM could improve certainty of our project *(TC_1)*. 2. We believed the information rich model could be very useful throughout the project lifecycle *(TC_2)*.	Crotty (2013) Kensek (2015)

	3. We believed the robustness of BIM software could save our time in delivering project outcomes *(TC_3)*.	Akinade et al. (2016)
	4. We felt safe to share the files in our project Common Data Environment *(TC_4)*.	Fan et al. (2018)
	5. We believed the clear BIM workflow could provide better understanding of our responsibilities in the project *(TC_5)*.	Fan et al. (2018)
	6. We believed the BIM workflow was fairly designed *(TC_6)*.	Fan et al. (2018)
	7. We believed the BIM workflow was designed based on our shared understanding *(TC_7)*.	Fan et al. (2018)
	8. We believed the synchronous and/or asynchronous communication tools we used had enough functions to facilitate our project discussion *(TC_8)*.	Ejdys (2018); Venkatesh and Bala (2008)
	9. We believed the synchronous and/or asynchronous communication tools were secured enough for having our project discussion *(TC_9)*.	Ejdys (2018); Venkatesh and Bala (2008)
	10. We believed the quality of connection provided by the synchronous and/or asynchronous communication tools was smooth enough to facilitate our project discussion *(TC_10)*.	Ejdys (2018); Venkatesh and Bala (2008)
	11. We believed the synchronous and/or asynchronous communication tools were user friendly enough to facilitate our project discussion *(TC_11)*.	Ejdys (2018); Venkatesh and Bala (2008)
Interorganizational trust (IT)	1. We believed our team members always kept their promises *(GT_1)*.	Chen et al. (2017)
	2. We believed our team members always acted fairly in negotiations *(GT_2)*.	Lui and Ngo (2004)
	3. We believed our team members could be counted on to act as expected *(GT_3)*.	Lui and Ngo (2004)
	4. We believe when an incident occurs, our team members would inform us immediately and act accordingly *(GT_4)*.	Jiang et al (2016)
	5. We believed our team members always performed based on the roles and responsibilities assigned to them *(CT_1)*.	Chen et al. (2017)
	6. We believed our team members always showed their professionalism in the collaboration process *(CT_2)*.	Chen et al. (2017)
	7. We believed our team members could perform based on the capacity of their resources and/or reputations they earned *(CT_3)*.	Lui and Ngo (2004)
	8. We believed our team members were capable in undertaking their responsibilities based on their qualification and/or experience *(CT_4)*.	Lui and Ngo (2004)
Obligatory Cooperation (*OC*)	1. Our team members performed the responsibilities defined in the description of the roles *(OC_1)*.	Quanji et al (2017)
		Quanji et al (2017)

	2. Our team members fulfilled the tasks as expected, which formed parts of their roles *(OC_2)*.	Quanji et al (2017)
	3. Our team members met the performance expectation *(OC_3)*.	Quanji et al (2017)
	4. Our team members complied with the rules and regulations that set out in the project. *(OC_4)*.	
Voluntary Cooperation (*VC*)	1. Our team members willingly did things that were beyond their responsibilities to achieve better project performance *(VC_1)*.	Quanji et al (2017)
	2. Our team members willingly provided innovative recommendations to improve project performance *(VC_2)*.	Quanji et al (2017)
	3. Our team members willingly oriented new members in the project *(VC_3)*.	Quanji et al (2017)
	4. Our team members willingly followed the policies of the project organisation *(VC_4)*.	Quanji et al (2017)
	5. Our team members willingly accepted the decisions made by the project owner *(VC_5)*.	Quanji et al (2017)
	6. Our team members willingly did what the project owner expected, even when considering it not to be important *(VC_6)*.	Quanji et al (2017)

Table 3. Basic information of respondents and projects

Item	Indicators	Proportion
The primary nature of the firm	Developer/owner/ representative of a government agency	6%
	Architectural Design Consultant	20%
	Engineering Design Consultant	8%
	Cost and Contract Consultant	14%
	Project Management Consultant	9%
	Construction Firm	34%
	Subcontracting Firm	1%
	Other	8%
The highest level of BIM that was used in the project	Level 0 – Level 0 – 2D CAD.	5%
	Level 1 – 3D CAD and data sharing via extranet/EDMS	6%
	Level 2 – 3D model collaboration through common file formats	34%
	Level 2 – 3D & 4D models collaboration through common file formats	9%

	Level 2 – 3D, 4D & 5D models collaboration through common file formats	12%
	Level 2 – Level 2 – 3D, 4D, 5D & 6D models collaboration through common file formats	19%
	Level 3 – All models were integrated as a single model in a central repository which can be accessed and modified by all model	3%
	contributors	12%
	Not sure which level was used	
Frequency of communication with team members (via virtual meeting tools, messaging apps, emails and phones)	Once a month	8%
	Once fortnightly	5%
	Less than three times per week	47%
	≥ three times per week	40%
The contract delivery model for the project	Design-bid-build	46%
	Design and build/Turnkey	33%
	Management contracting	10%
	Other	11%
Project duration	< 2 years	19%
	2 < 5 years	72%
	≥ 5 years	9%
Contract value	< RM 100 million (about 25 million USD)	18%
	RM 100 million <RM500 million	46%
	RM 500 million < RM 1 billion	26%
	≥ RM 1 billion	10%
Age	20 < 30 years old	49%
	30 < 40 years old	30%
	40 < 50 years old	16%
	50 < 60 years old	3%
	≥ 60 years old	2%
Years of working experience	< 5 years	37%
	5 <10 years	34%
	10 < 20 years	20%
	20 < 30 years	8%

	≥ 30 years	1%
Role	Senior management	24%
	Junior management	23%
	Executive	36%
	Other	17%

Table 4. Results of measurement models for the trust in communication technology model

Constructs	Indicators	Outer loadings	Cronbach's Alpha	CR	AVE
Trust in communication technology (TC)			0.87	0.90	0.60
	TC_ 6	0.70			
	TC_7	0.70			
	TC_8	0.82			
	TC_9	0.81			
	TC_10	0.79			
	TC_11	0.85			
Interorganizational trust (IT)			0.89	0.91	0.60
	CT_ 1	0.75			
	CT_ 2	0.80			
	CT_ 3	0.81			
	CT_ 4	0.84			
	GT_1	0.72			
	GT_2	0.74			
	GT_3	0.77			
Voluntary Cooperation (VC)			0.88	0.91	0.62
	VC_1	0.77			
	VC_ 2	0.78			
	VC_ 3	0.88			
	VC_ 4	0.88			
	VC_5	0.71			
	VC_6	0.72			

Obligatory Cooperation (OC)			0.87	0.91	0.73
	OC_ 1	0.82			
	OC_ 2	0.89			
	OC_ 3	0.88			
	OC_ 4	0.82			

Table 5. Heterotrait-Monotrait Ratio (HTMT) values

	IT	OC	TC
OC	0.795		
TC	0.507	0.516	
VC	0.701	0.873	0.607

Table 6. Overall results of hypotheses testing

Hypos.	Type of effect	Path	Coeff.	*t* value	*p* value	Sig. level	Lower bound (5%)	Upper bound (95%)	Result (Supported or not)
H1	Total Effect (c’)	H2+H3+H4+c	0.481	4.255	0.000	***	0.276	0.620	Yes
	Direct effect (c)	TC > IT	0.119	1.129	0.259	ns	-0.079	0.310	No
H2	Indirect effect	TC > OC> IT	0.242	2.523	0.012	**	0.104	0.413	Yes
H3	Indirect effect	TC> VC> IT	0.040	0.806	0.420	ns	-0.011	0.128	No
H4	Indirect effect	TC > OC> VC > IT	0.050	1.017	0.309	ns	-0.019	0.127	No

Note: *, **, ***, and ns indicate a significance level of p<0.1, p<0.05, p<0.01, and no significance, respectively, based on bootstrapping of 5,000 subsamples and a significance level of 10%.

Table 7. Coefficient of Determination (R^2) and blinding and predictive relevancy (Q^2)

Endogenous Latent Variable	R^2	Q^2
IT	0.551	0.288
OC	0.228	0.136
VC	0.641	0.351

Table 8. Effect size f^2 *and* q^2

	f^2			q^2		
	IT	OC	VC	IT	OC	VC
IT						
OC	0.273		1.006	0.091		0.328
TC	0.051	0.327	0.140	0.010	0.157	0.037
VC	0.040			0.004		