Joint-contract function effects on BIM-enabled EPC project performance

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Abstract: Engineering, procurement, and construction (EPC) contracting does not promote collaboration and thus, may not be suitable for building information modeling (BIM) projects. Joint-contract functions that combine contractual control, coordination, and contingency adaptability may positively influence the performance of these BIM-enabled projects. This study hypothesized that perceived fairness, calculative trust, relational trust, and positive outcomes of distrust influence the relationship between joint contract functions and BIM-enabled project performance. It collected 252 observations from industry practitioners in EPC oil and gas projects and analyzed them using partial least squares structural equation modelling (PLS-SEM). The results show no direct effect of joint-contract functions on BIM-enabled EPC project performance but do show significant total and indirect relationship effects that are influenced by perceived fairness and relational trust. The findings contribute to construction contracting research by empirically showing how formal contracts focusing on joint-contract functions can influence BIM-enabled EPC project performance. The current findings also shed light on appropriate contract framing for BIM-enabled EPC project stakeholders, an area not explored in the previous literature.

Keywords: Contract Functions, Control; Coordination; Contingency Adaptability; Trust; Distrust; Building Information Modelling (BIM); Engineering, Procurement, and Construction (EPC)

Introduction

The use of building information modeling (BIM) has become prevalent in various industries. It is not only a digital representation used to plan, design, control, and maintain facilities, it also affects the conventional ways that project participants define their roles and collaborate (Liu et al. 2017). Several studies argue that conventional contracting—including the engineering, procurement, and construction (EPC) approach—is not suitable for projects that implement BIM (e.g., Lee et al. 2018). The goals of EPC-contracting parties can conflict in the following sense. First, an owner aims to complete a project within a certain timeframe and budget and according to desired specifications, whereas a contractor aims to make the highest possible profit from the project (Berends 2007). The conflicting positions between the owner and the EPC contractor can give rise to opportunism, in which both parties do anything to realize higher gains, regardless of the expense to the other (Lu et al. 2016). In addition, the nature of EPC projects, which typically involve high asset specificity and uncertainties, further increases the possibility of opportunistic behaviors by the contracting parties (Lee et al. 2018). As such, EPC contracts grounded in transaction law (Williston and Lewis 1920) and in a transaction cost economics approach usually impose more thorough contractual obligations. On the one hand, more thorough contracts enable parties to minimize uncertainty and thus restrain potential opportunistic behaviors (Williamson 1985). On the other hand, the contracts can have detrimental effects on cooperation in a BIM work environment (Goshal and Moran 1996; Wuyts and Geyskens 2005). The possibility of detrimental effects prompts the overarching question of what complementary approaches can best facilitate BIM implementation in EPC contracts.

Prior research has demonstrated that formal contracts can restrain relational norms and may result in distrust between the parties (Malhotra and Murnighan 2002). However, formal contracts also have the potential to facilitate the development of close, cooperative relationships by better aligning the expectations of parties (Mayer 2007). Schepker et al. (2014) provided some important insights, including the observation that firms should focus on the functional approach in contracting to succeed in their transactions. There are three main contract functions in an exchange: control, coordination, and contingency adaptability (Eckhard and Mellewigt 2006). To protect the contracting parties, the control function defines tolerable behaviors and applicable sanctions in BIM implementation (Benaroch et al. 2016). It is also used to reduce transaction and administration costs (Teng et al. 2019). Contractual coordination aligns the expectations of contracting parties by harmonizing the resources and activities required for delivering BIM (Eckhard and Mellewigt 2006). In the context of this study, contingency adaptability (or "adaptation") refers to the provisions or guidelines for handling unanticipated situations that arise from using BIM (Luo 2002). Formal contracts often describe a mutually agreed tolerance zone for handling unexpected circumstances and conflicts arising from using BIM. These can include solutions for delays that result from ineffective collaboration among team members (Li et al. 2019), data error, or data loss. These solutions and guidelines are included in engineering and construction contracts as independent terms (e.g., procedures for handling delays due to BIM imperfections) or as clauses related to specific areas (e.g., dispute resolutions, damages stemming from the use of BIM, etc.).

In this paper, it is argued that BIM in EPC projects can be implemented more effectively through the lens of joint-contract functions. This approach enables firms to pay closer attention to all three functions of formal contracts to improve exchange efficiency. In related previous studies, Wang et al. (2017) investigated the impact of contractual control, coordination, and adaptation on various aspects of relationships (such as prior interactions, standard levels of cooperative behavior, and voluntary cooperative behaviors) and Quanji et al. (2016) investigated the relationships between contractual control, coordination, adaptation, and contractual partners' voluntary and obligatory cooperation. The two studies showed the usefulness of joint-contract functions in investigating cooperative behaviors. These functions can also improve project performance in BIM. As there is more potential for EPC contracting parties to engage in opportunistic behaviors, joint-contract functions can play an important role in effective governance for projects involving BIM. Contractual control reduces opportunistic behaviors, and contractual coordination and contingency adaptability foster interorganizational trust between owners and contractors, all of which enhance cooperative behaviors between contracting parties and contribute to improved performance.

Combining the three main contract functions also helps mitigate adverse effects from the individual contract functions, which also positively affects BIM-enabled project performance (Lee et al. 2018). For example, high levels of control breed low levels of trust (Faulkner 2000), whereas a contract environment that emphasizes coordination and contingency adaptability can build and strengthen trust, thus leading to better BIM performance (Lee et al. 2018). The authors of the current paper argue that interorganizational trust may influence the effect of joint-contract functions on project performance. In a previous study on the effects of contracts on trust, Jiang et al. (2016) showed that contracts influence relational trust positively, but they did not explore how contracts influence relational trust and contribute to project success. Moreover, distrust (which is often perceived in contractual contexts) can have a pernicious effect on exchange performance but may have a positive impact on project performance (Lee et al. 2018). Furthermore, a contractual relationship that favors fairness can reinforce trust, thus leading to more effective collaboration (Benítez-Ávila et al. 2018). Perceived fairness is another important variable that could mediate interorganizational trust and influence the relationship between joint-contract functions and BIM-enabled project performance.

Against this background, this study aims to determine the direct effect of joint-contract functions on BIM-enabled EPC project performance, and it also explores the mediating effects of perceived fairness, interorganizational trust, and distrust. To test the research hypotheses, the study employs partial least squares structural equation modeling (PLS-SEM) based on 252 questionnaire answers from industry practitioners involved in EPC oil and gas projects, and it quantifies the direct effect of joint-contract functions on BIM-enabled project performance as a complementary approach to EPC contracts. To the authors' knowledge, this is the first attempt to empirically investigate the effects of formal contracts on BIM-enabled project performance through the lens of joint-contract functions. Another area that has not been examined by previous studies is the potential mediating effects of calculative trust and distrust, relational trust, and perceived fairness between the contracting parties. By illuminating the effects of joint-contract functions on EPC BIM-enabled project performance (and by incorporating the mediating variables discussed above), this study provides more realistic guidelines for the construction of EPC contracts based on joint-contract functions, which promote effective collaboration in a BIM working environment.

The remainder of the paper is structured as follows. The second section discusses the theoretical background and presents hypotheses that describe the relationships between joint-contract functions, perceived fairness, interorganizational trust, and project performance. The third section clarifies the research design, including the sampling, data collection procedures, data analysis methods, and the applied measures. The fourth section presents the analysis of the hypothesized model. The fifth section discusses the contributions and limitations of the approach, as well as possible directions for future research. The last section concludes the paper.

Theoretical background and hypotheses development

Joint-contract functions and EPC BIM-enabled project performance

As previously discussed, in the EPC approach, which emphasizes contracts and transaction law, formal contracts are wielded as instruments of control (Williston and Lewis 1920; Dyer 1997). Furthermore, formal contracts that overly focus on control mechanisms can inhibit relationship development, thereby preventing the benefits of BIM from being fully realized (Huber et al. 2013). However, some degree of contractual control is necessary when using BIM to mitigate the risk of exploitation (Das and Teng 1996). Contractual control not only allows for behavioral control, such as through stipulating damages arising from breaching terms of BIM use, but it can also take the form of input and output controls throughs terms that stipulate BIM deliverables. Despite some of the detrimental effects of contractual control, Lumineau and Hendersen (2012) show that contractual coordination can actually strengthen the cooperative interaction between the contracting parties. Contingency adaptability provisions can hinder strategic flexibility (Malhotra and Lumineau 2011), but they can also enable the contracting parties to share knowledge while managing the changes associated with BIM (Reuer and Devarakonda 2016).

There are numerous criteria for measuring successful project performance (Mir and Pinnington 2014). The most common include the satisfaction of team members, value added to the organization, the timeliness of projects, adherence to budgets and to the desired quality of work, and effectiveness of interactions between team members (Thompson et al. 2007). Contractual coordination and contingency adaptability reinforce collaboration among team members in a BIM work environment by facilitating the intensive sharing of knowledge and information (Zheng et al. 2017). As such, it is hypothesized that coordination and adaptability directly influence the effectiveness of the interactions between team members, thus increasing their work satisfaction. The harmonization between contractual control, coordination, and contingency adaptability may also enhance the quality of BIM deliverables and ensure optimal project performance. Parties that acknowledge the advantages of using functional contracting can more easily achieve better outcomes compared with those that focus less on functional contracting (Mellewigt et al. 2007). Hence, the following is hypothesized:

H1: Joint-contract functions positively and directly relate to project performance.

Mediation effect of interorganizational trust

Trust is "*a psychological state which comprises the intention to accept vulnerability based upon positive expectations of the intentions or behavior of another*" (Rousseau et al. 1998, p. 395). Specifically, interorganizational trust is a firm's expectation that another firm will not behave opportunistically (Bradach and Eccles 1989). Interorganizational trust thus allows two firms to exchange information and share responsibilities for decision-making (Zaheer et al. 1998). Interorganizational trust includes calculative, relational, and institution-based trust (Rousseau et al. 1998). The aim of the current study is to determine how contract provisions represented by joint-contract functions impact the trust between firms. Thus, the study considers calculative and relational trust. Institutional trust, on the other hand, is affected by institutional practices and exchange routines and is not part of the current analysis (Zaheer et al. 1998).

Calculative trust arises from the positive and negative consequences that are predicted by parties who are participating in a collaboration (Williamson 1993), and joint-contract functions can influence the calculative judgement of parties in their evaluation of risks and potential payoffs. For BIM, contract control may stipulate the damages to be paid, for example, in the event of copyright infringements claimed by a third party. Contractual coordination allocates the responsibilities of the parties in sharing, maintaining, and using the model, and it enables parties to assess the magnitude and quality of efforts they must make in these processes. On the other hand, contingency adaptability allows parties to make rational judgements about the risks they bear in case of technical errors during BIM development. These functions support calculative trust by allowing parties to consider the legal and economic consequences of breaching contracts (Lumineau 2017).

Jiang et al. (2016) demonstrated that, compared to calculative trust, relational trust has a more significant effect on project performance. Relational trust is developed through reciprocity and social-emotional exchange, which require a higher level of confidence in the partner (Rousseau et al. 1998). Appropriate contractual control and contingency adaptability give parties more confidence when sharing information within a BIM working environment, since mutual interests are protected and uncertainties are reduced. Through promoting information sharing and collective decision-making in a BIM environment, coordination and contingency adaptability provisions foster relationships between parties. Several studies reveal that trust is closely connected to project performance. For instance, interorganizational trust has positive effects on cost performance improvement (Li et al. 2018). Furthermore, trust moderates the relationship between manager relational exchanges and project performance (Chen and Lin 2018). Trust also affects communication and, therefore, influences project performance (Cheung et al. 2013). Hence, the following are hypothesized:

H2: Calculative trust has a positive influence on the relationship between joint-contract functions and project performance.

H3: Relational trust has a positive influence on the relationship between joint-contract functions and project performance.

Mediating effect of interorganizational distrust

Trust and distrust should be investigated separately since they are two distinct constructs (Dimoka 2010). In this study, distrust refers to the state of being influenced by calculative judgement. Contractual control allows for the easier identification of instances in which one or the other party deviates from the contract terms. Thus, it supports the enforcement of contractual terms (Lumineau 2017) and makes contracts more proficient in terms of the logical judgements that motivate assumptions about the other party. Contractual controls also promote calculative distrust. For example, calculative distrust can be associated with the following scenarios: the protection of the intellectual property rights of BIM model contributors, auditing a model to ensure the conformance of project deliverables, and stipulating damages arising from the third party copyright infringement, among others. The contractual controls promote calculative distrust—in other words, constructive skepticism and vigilance—safeguarding the interests of both parties involved in the contractual relationship (Lumineau 2017). The informed awareness that emerges from calculative distrust prompts the contracting parties to take appropriate measures to mitigate risks (Smyth et al. 2010). In other words, trust and distrust are simultaneously managed in this kind of antagonistic environment, in which parties are as likely to distrust as they are to trust one another (Lewicki et al. 1998). This implies that distrust may correlated with project performance, particularly if the parties experience increased trust after a successful collaboration and transaction. Trust can positively affect a transaction when fear and skepticism are minimized through appropriate distrust-related contract provisions (Lee et al. 2018). Hence, the following is hypothesized:

H4: Calculative distrust has a positive influence on the relationship between joint-contract functions and project performance.

Multiple mediating effects of perceived fairness and interorganizational trust

When the fairness principle is applied to construction projects, both parties in a contract should hold equal positions for gaining economic advantage. When parties perceive there is fairness in the transaction, they will exhibit positive behaviors that can improve project performance, such as resolving problems collaboratively, working harmoniously, and engaging in mutual support, all of which are essential for success in BIM-enabled projects (Lim and Loosemoore 2017). Perceived fairness can reduce the potential for dissatisfaction and conflicts and bolster the legitimacy of organizational procedures. In construction research, perceived fairness has been shown to affect claims and disputes (Spittler and Jentzen 1992). In these ways, perceived fairness affects the cooperative behaviors of employees and the operational efficiency of firms (Greenberg 1989).

There are two types of perceived fairness that influence decision-making: distributional and procedural fairness. To achieve distributional fairness, the material outcomes of a cooperative effort must be compatible with the perceived outcomes (Adams 1965). Procedural fairness not only pertains to material outcomes but also to the process used to reach those outcomes (Leventhal 1980). Contract functions can affect both types of fairness. Contractual coordination and contingency adaptability affects procedural fairness by specifying the ways in which parties involved in BIM collaborate, such as in the strategic coordination of BIM development in stages through mutual discussions and procedures to prevent conflicts from arising. Procedural fairness can induce a broad range of emotions in employees, including the feeling of being respected, feeling loyalty to and recognized by a company, feelings of trust, and work commitment (Collet 2008). Contractual control, which stipulates damages from a breach of terms in BIM delivery, affects distributional fairness, which in turn influences efficiency and productivity (Suliman 2007). It may be difficult, however, to realize absolute fairness (Lau and Rawlinson 2009). In light of the above discussion, the following are hypothesized:

H5: Perceived fairness and calculative trust jointly and positively influence the relationship between joint-contract functions and project performance.

H6: Perceived fairness and relational trust jointly and positively influence the relationship between joint-contract functions and project performance.

Multiple mediating effects of perceived fairness and interorganizational distrust

Perceived fairness also impacts the positive outcomes of calculative distrust through joint contract provisions. For example, control provisions may include requirements for compliance audits and for the payment of damages for copyright infringement. These provisions invoke the distributional and procedural judgements of parties and motivate the careful monitoring of activities during BIM use (Provan and Skinner 1989), and the scrutinizing of actions that diverge from agreed-upon terms (Klein and Murphy 1988). Fairness plays an important role in mediating joint-contract functions, thus encouraging the positive outcomes of distrust. Specifically, fairness has to do with the way individuals are treated and the sense of justice that comes from the sharing of rewards (Lau and Rawlinson 2009). When perceived fairness influences distrust provisions, it may impact project performance. Therefore, the following is hypothesized:

H7: Perceived fairness and calculative distrust jointly and positively influence the relationship between joint-contract functions and project performance.

Research methodology

Data collection

To collect relevant data, the researchers approached approximately 1,200 construction-related practitioners worldwide via LinkedIn, most of them from oil and gas conferences and workshops. It took two years to collect the contact details of all the practitioners who were involved in planning, construction, engineering, contract, and information management of EPC oil and gas projects. This kind of project was selected for two reasons. First, oil and gas projects have exploited BIM for over 20 years. Second, the maturity of the BIM used in oil and gas projects made it easier to conduct an investigation to identify the impact of contract functions on BIM-enabled project performance, and EPC is one of the most popular project delivery methods used in oil and gas projects.

The survey, which consisted of four sections, was distributed to respondents, who answered questions based on their most recent projects. Section A of the survey inquired about the project and personal details. To help respondents understand and respond to the survey, BIM was referred to as three-dimensional (3D); four-dimensional (4D, Construction Sequencing); five-dimensional (5D, Cost Estimation); and six-dimensional (6D, Asset Lifecycle Management) modeling and its associated technologies; and/or digital data involved in the design, production, and maintenance process. Oil and gas projects were referred to as projects related to building facilities for oil, gas, and their derivatives (e.g., methanol, fertilizers). This included drilling and production platforms; floating production storage and offloading systems (FPSO); floating liquefied natural gas (FLNG); onshore oil and gas plants; and other related infrastructure (e.g., pipeline, jetty, and ship loading facilities). Sections B, C, and D comprised questions on the measurement items for the contract functions related to BIM, interorganizational trust and distrust, and project performance, respectively. Each variable consisted of four measurement items except for project performance, which consisted of seven measurement items. A two-round pilot survey was conducted to validate and revise the draft questionnaire as required (Jiang et al. 2016). In the first round, the questionnaire was distributed to three experts in oil and gas contracts and engineering and project management, respectively. After revising the questionnaire, it was sent to nine oil and gas project practitioners for further comments. The questionnaire was then revised until it was suitable for online distribution, which took place from May to July of 2018. The time frame given for responding to the survey was two weeks. A follow-up reminder was sent five days before the response expiry date. In total, 276 responses were collected, with 2.6% of surveys having some missing values. Following the assertion by Schafer (1999) that a missing rate of 5% or less is inconsequential, the observations with missing data were removed from the dataset. After elimination, the sample comprised 252 responses. Although the PLS-SEM algorithm has a bootstrapping feature to deal with skewed data, Hair et al. (2014) suggested that the skewness and kurtosis of the data should be + or -1. The data used for analysis in PLS-SEM that had a skewness exceeding 1 were transformed to ensure they fell within the limits of +1 or -1.

Data analysis method

PLS-SEM was used to determine the influence of joint-contract functions on project performance and gauge any mediating effects on the relationship. This method was selected for its precision in prediction-oriented analysis compared with covariance-based SEM (CB-SEM) as well as for its ability to deal with complex models (Rigdon et al. 2017). Moreover, the bootstrapping feature available in the PLS-SEM algorithm allowed for a more robust study of skewed data and formative measures, as it transformed the data under the central limit theorem (Ringle et al. 2009).

Sample data

Referring to Appendix 1, the respondents who worked with project owners represented 44% of the sample and the EPC contractors, 56%. Most of the involved firms have operated for over 50 years, and their projects were mostly onshore plants and other associated facilities and in Asia, North America, and Oceania. The contract values for most projects were above USD 500 million with durations of 2–5 years. Additionally, most respondents had more than 20 years of working experience in the construction industry, as project managers (37%), contract managers (13%), engineering managers (13%), construction managers (12%), information managers (7%), project control managers (6%), and in other related roles (13%). Oil and gas projects were found to fall significantly under the three-dimensional shared information model (40%), with 32% of respondents stating that the shared information model used in the projects included digital fabrication. Although 46% of respondents stated that the projects did not include other BIM uses, 30%, 16%, and 8% of respondents mentioned the projects applied a four-dimensional model for construction sequencing, a five-dimensional model for cost estimation, and a six-dimensional model for asset lifecycle management, respectively.

To assess sampling error, the potential non-response bias was evaluated. Lindner et al. (2001) suggested investigating this type of bias through an independent t-test to compare the significant differences between early and late responses. As there is no consistent definition for "late respondents," they were stipulated as those who answered the survey after receiving the reminder email. The outcomes indicated no non-response bias, since the difference between early and late responses was not significant. After cleaning the data, the authors examined missing values using Little's missing completely at random test. The outcomes of the test showed that the Chi-square was 48.405 with DF = 40 and Sig. = 0.170, which was not significant. This suggested that missing values were random. The number of missing values was 2.6%, where a 5% or lower missing rate was considered insignificant (Schafer 1999). Hence, the observations with missing data were removed from the dataset.

Measures

The measurement items for contract functions were obtained from prior studies and BIM contract protocols. The respondents were given an opportunity to clarify any doubts before responding to the questions. Some items for contract functions may have looked similar but had different meanings. For instance, contractual control was measured by the specified contract terms that defined a right to audit for conformance in delivering BIM (*CON_1*) and stipulated damages against the party that failed to comply with the terms related to BIM deliverables (*CON_2*). Contractual control was also measured by general controlling and monitoring of BIM deliverables terms (*CON_3*), such as the requirements of contracting parties to deliver BIM as specified in the contracts, and the terms that specified solutions for non-conformance of BIM deliverables (*CON_4*). For *COR_4*, contractual coordination provided dispute resolution provisions for parties to achieve collective action to deal with the conflicts arising from delivering BIM, which is different from contractual control.

The measurement scales for project performance, perceived fairness, calculative trust, and relational trust in Table 1 draw from measurement scales validated in prior studies. Calculative distrust was measured following the literature (Lumineau 2017). All construct indicators were measured using 5-point Likert scales, ranging from strongly disagree to strongly agree or from extremely low to extremely high. Reflective constructs formed the indicators. All constructs were reflective, except for the joint-contract function, which was formative. Thus, the three contract functions—contractual control, coordination, and contingency adaptability—influenced the joint-contract functions. Although joint-contract functions were interpreted as formative constructs, they repeated the indicators in the three contract functions. Since joint-contract functions had a reflective measurement model, as in Figure 1, all relevant reliability and validity tests had to be cleared when measuring the reflective model, with the exception of the discriminant validity between the three distinct and joint-contract functions (Hair et al. 2014).

Results and data analysis

SmartPLS 3.0 was used to analyze the measurement models and the structural model. The assessment followed Hair et al. (2014).

Evaluation of measurement models

The indicators in a reflective construct must be consistent with each other within the construct. To measure internal consistency reliability, the suggested Cronbach's alpha's value should range from 0.70 to 0.90 (DeVellis 2016) to demonstrate the intercorrelations of a set of items. Table 2 shows that all Cronbach's alpha values are below 0.90, except for joint-contract functions, which had a value of 0.927. However, it is less accurate to assess internal consistency reliability using this measure, as it is responsive to the number of items measured on a scale (Hair et al. 2014). Composite reliability (CR) is a more reliable internal consistency measure. It considers the different outer loadings of indicators, measurement errors of the indicators, and their variances. Table 1 shows that all constructs had CR values below the 0.95 threshold (Hair et al. 2014). All outer loadings of indicators were above the 0.70 threshold, except for the contractual control that stipulated damages against the party failing to deliver the digital model and/or data, with the value of 0.609 in the joint-contract functions construct. This control was removed from the model. The values of the outer loadings of contractual control defined the right to audit for conformance in delivering the digital model and/or data in the joint-contract functions construct; the distrust construct, in which one party was constructively skeptical about the other party, enabled better work in the project; project performance constructs, which indicated the outcome of the project, added value to the organization's operations; and the project satisfying health and safety performance expectations were also below the threshold, at 0.672, 0.673, 0.686, and 0.649 respectively. Nevertheless, indicators with outer loading values ranging from 0.40 to 0.70 should be removed if removal increases the value of CR or the average variance extracted (AVE) (Hair et al. 2014). The deletion of these indicators reduced the CR value; hence, they were retained in the model. Simultaneously, AVE was used to assess the extent to which an indicator correlated positively with other indicators of the same construct (Hair et al. 2014). The values of the AVEs of all constructs were above the 0.50 threshold, demonstrating that the indicators in the constructs converged.

Discriminant validity is another important measure that analyzes the differences between constructs. This measure shows a construct is distinguished from other constructs in a model and captures a different phenomenon. In PLS-SEM, the heterotrait-monotrait ratio (HTMT) of correlations is a new measure that assesses discriminant validity, as the Fornell–Larcker criterion and cross-loadings do not detect discriminant validity reliably in some situations (Henseler et al. 2015). Table 3 shows the HTMT value between contractual coordination and contingency adaptability is 0.950. Henseler et al. (2015) suggested that indicators with low correlations should be removed to reduce HTMT values. Hence, the lowest outer loading values for contractual coordination (which delegates the roles of parties for delivering BIM and provides dispute resolution provisions to deal with any conflicts) were removed (Table 2), which reduced the HTMT value to 0.885.

Common method variance

The evaluation of common method variance is important since it influences the validity and reliability of measurement models (Podsakoff et al. 2003). This type of systematic error occurs when a single source of research design is used (Schaller et al. 2015). This study may be affected by common method variance, as the data were collected through a single source, that is, an online survey. Harman's (1976) single-factor test is a common method used to assess variance. The result of the analysis showed a variance of 24.13%, meaning that it was unlikely the common method variance affected the study outcomes (Podsakoff and Organ 1986). The full collinearity test is a reliable method proposed by Kock (2015) to determine common method variance in PLS-SEM research. The accepted criterion for variance inflation factor (VIF) values is that it should not be above 3.3 when using the PLS-SEM algorithm (Kock 2015). The test in this study showed that all VIF values of the constructs were below 3.3, indicating no common method variance.

Structural model evaluation

To examine the structural model, Stone-Geisser's Q^2 value was calculated to evaluate the predictive relevance of indicators. All constructs had positive Q^2 values (calculative trust = 0.081; calculative distrust = 0.041; relational trust = 0.137; perceived fairness = 0.055; joint-contract functions = 0.569; and project performance = 0.11), indicating the predictive relevance of the path model for the constructs. Next, the coefficient of determination (R^2 value) was used to assess the predictive accuracy of the model. R^2 values range from zero to one. The higher the R^2 value, the higher the predictive accuracy. In research related to predicting the drivers of success, an R^2 value of 0.20 is considered high (Hair et al. 2014). In this study, project performance had the highest R^2 value (0.233), followed by relational trust (0.225), calculative trust (0.150), calculative distrust (0.098), and perceived fairness (0.092). In addition to the evaluation of R^2 values, the effect size f^2 was used to evaluate the substantive impact of a variable when removed from the model.

The small, medium, and large effect sizes were represented by the f^2 values of 0.02, 0.15, and 0.35 respectively (Cohen 1988). Table 4 shows that all exogenous variables had at least small effects on the endogenous variables, except for calculative distrust on project performance and joint-contract functions on calculative trust and project performance, with f^2 values of 0.000, 0.010, and 0.009, respectively. Comparing the f^2 values of the variables shows that relational trust and perceived fairness were the endogenous variables in the model. Relational trust was affected by both perceived fairness (medium effect, f^2=0.165) and joint-contract functions (small effect, f^2=0.046), whereas perceived fairness was solely affected by joint-contract functions (small effect, f^2=0.102). Calculative trust was partially endogenous, as it was affected by perceived fairness (small effect, f^2=0.127) but not joint-contract functions.

The constructs' path coefficients were then analyzed. Bootstrapping was conducted for 5,000 iterations to identify the *t*-values, *p*-values, and confidence intervals of the paths (Palanski et al. 2011). Table 5 shows that, although the direct effect between joint-contract functions and project performance is 0.09 and the p-value is not significant, the joint-contract functions had a significant total effect ($\beta = 0.227$, $p < 0.01$) and indirect effect ($\beta = 0.136$, $p < 0.01$) on project performance. Hence, **H1 is partially supported.** Table 4 also shows that there was no significant effect of calculative trust on joint-contract functions and project performance ($\beta = 0.230$, $p > 0.10$); therefore, **H2 is not supported.** In contrast to calculative trust, relational trust was a significant mediator variable between joint-contract functions and project performance ($\beta = 0.058$, $p < 0.01$), showing that **H3 is supported.** The results in Table 5 also show that calculative distrust insignificantly influenced the relationship between joint-contract functions and project performance ($\beta = 0.001$, $p > 0.10$). Hence, **H4 is not supported.** In terms of multiple mediation effects, **H5 is supported**. Perceived fairness and calculative trust jointly influenced joint-contract functions and project performance ($\beta = 0.023$, $p < 0.10$). **H6 is also supported,** since perceived fairness and relational trust jointly influenced joint-contract functions and project performance ($\beta = 0.031$, $p < 0.05$). However, **H7 is not supported**, as perceived fairness and calculative trust did not jointly mediate contract functions and project performance ($\beta = 0.000$, $p > 0.10$). Figure 2 shows the final model for joint-contract functions and project performance.

Moderating effects analysis

To determine whether the relationships in the structural model were influenced by different project scopes and types, a moderating effects analysis was conducted with the finding that relationships between constructs in the model were not influenced by scopes (e.g., FPSO, FLNG, and other plants) and types of projects (locations, values, and durations) with the exception of the paths in Table 6.

Table 6 and Figure 3 show that the positive relationship between joint-contract functions and relational trust was stronger for projects located onshore but the relationship turns negative for the projects located offshore. The relationship between joint-contract functions and calculative distrust was positive for both low and high contract values. This relationship was stronger for projects with higher value. Project duration moderated the relationship between calculative distrust and project performance such that for shorter project durations, the effect was negative, and for longer project durations, it was positive. By contrast, the relationship between joint-contract functions and project performance was stronger for projects with a longer duration but weaker when the project duration was shorter.

Discussion and contributions

Joint-contract functions and the mediating effect of relational trust

The results above provide new insights, including the observation that joint-contract functions indirectly influence BIM-enabled EPC project performance through perceived fairness and relational trust; this is despite the fact that the effects of joint-contract functions on relational trust are not so pronounced in offshore projects. The results are different from prior research in that formal contracts tend to restrain the establishment of relational norms between contracting parties (Malhotra and Murnighan 2002). The outcomes of this study explain how joint-contract functions can be used as a complementary approach to EPC BIM-enabled projects, an area hitherto not empirically examined. The moderation analysis shows that, when the EPC project duration is longer, the relationship between joint-contract functions and a BIM-enabled project performance is stronger. These outcomes suggest that the conventional approach of EPC contracts that focused on imposing contractual obligations to safeguard transactions is no longer an effective governance method for long-term BIM-enabled projects. In a BIM working environment, enhancing contractual coordination and contingency adaptability, in addition to formal control, has implications on relational development and, thereby, leads to EPC project success. These functions include providing operational coordination for parties to discuss the necessary adjustments that need to be made to the BIM model upon the completion of the model review, redefining the specific objectives of the BIM model through mutual discussions upon the completion of the first-stage model development, and achieving collective action for handling unforeseen circumstances that may involve BIM. For EPC project success, construction contracting parties should view formal contracts as a mechanism to achieve a shared purpose instead of a tool that solely protects their benefits and interests. Focusing on contractual coordination in BIM model development and on contingency adaptability for joint problem solving enables parties to implement BIM with dynamic efficiency and embed relational elements into the BIM working environment.

Perceived fairness as a cornerstone of joint-contract functions

Although Lumineau (2017) proposed that excessive contract functions may have negative effects on calculative and non-calculative trust, there is no study on how the extent of contract functions influences trust. This study shows that perceived fairness influenced the degree of calculative and relational trust and impacted EPC project performance positively and significantly. This suggests that an adequate level of joint-contract functions could be determined through the perceived fairness of both parties. This outcome broadens the views of EPC practitioners and suggests looking beyond the traditional EPC contract setting. Contracts that promote joint problem solving and fair risk allocation would clearly provide a team-building platform and help cultivate rapport between contracting parties (Cheung et al. 2009). Hence, EPC contracts should not be framed solely to benefit the client. Contracting parties should consider the fairness of terms when devising BIM-related contract provisions to maximize the potential for project success. For instance, EPC contractors should not be held responsible for the failure to deliver BIM, which may be outside their control, and appropriate time extensions should be granted so that contractors can rectify these errors or issues.

Distrust does not necessarily negatively impact project performance

This study also reveals a new perspective on distrust in terms of BIM-enabled EPC project performance. It is commonly believed that formal contracts increase partner distrust and in turn, induce non-cooperative behaviors (Wu et al. 2017). While joint-contract functions have a significant effect on calculative distrust (which does not warrant its significant effect on EPC project performance) the results demonstrate that they may not necessarily have negative implications for EPC project performance. The relationship between joint-contract functions and project performance is stronger when project duration is longer and contract value is higher. This substantiates the fact that calculative distrust in EPC projects is necessary to prevent knowledge leaks, support vigilance, and promote healthy suspicion and constructive skepticism against the other party's opportunistic behaviors, all of which can boost confidence and help both parties to perform better in BIM-enabled projects. Examples of functions that can have these effects include defining the right to audit for conformance in delivering BIM, controlling and monitoring BIM deliverables, and providing resolutions for non-compliance with the terms and conditions of delivering BIM.

Effective collaboration among project participants without altering existing EPC contract structure

Finally, the mediation effects of interorganizational trust between joint-contract functions and BIM-enabled EPC project performance demonstrate not only that owners and EPC contractors should collaborate more intensively to build trust but also that other project stakeholders with direct contractual relationships (such as specialist contractors and subcontractors) should be involved directly in the collaboration process. For example, as per Figure 4, the EPC project network is egocentric. Only the EPC main contractor plays a prominent role in communicating between owners and other project participants. The owner and other project participants are peripheral nodes in the project networks, and they depend on the main contractor to deliver and receive information. This practice is fragmented, as each of the project participants follows their own procedures (Fakhimi et al. 2017), and it increases asymmetric information and opportunistic behaviors (You et al. 2018). In fact, all project stakeholders are required to share and receive project information through a unified information model. There is very little trust involved at the beginning of projects, but social exchange relationships emerge as each party proves its trustworthiness. During the information sharing process, as the parties engage more deeply in EPC projects (Shapiro 1987), relational norms are established. As such, stakeholders in BIM contracts within EPC projects should strive to harmonize relationships with other stakeholders in both their formal and informal social networks. Ultimately, this will foster an effective and collaborative BIM work environment.

Limitations and future research directions

The current study has certain limitations. The PLS-SEM method used here is exploratory and different from CB-SEM. The CB-SEM approach uses strict measures of confirmatory factor analysis to validate a developed theory, while this study uses PLS-SEM for exploration and prediction. Additionally, the use of contract functions may be affected by the levels of BIM use in a project. As such, the results of this study may be influenced by BIM use levels, since BIM uses may vary by project.

There are several antecedents of joint-contract functions—such as BIM asset specificity, behavioral uncertainty, and environmental uncertainty—which require attention, as the extent of joint-contract functions that influence interorganizational trust may be affected by BIM transaction attributes. Further, interorganizational trust predecessors, such as communication and reciprocity, may strengthen the relationship between joint-contract functions and interorganizational trust. If the influences of these predecessors are empirically proven, then when devising BIM-related provisions, appropriate strategies should be considered to enhance these factors to optimize the influence of joint-contract functions on BIM-enabled project performance.

Since the model is an aggregate of three different contract functions (joint-contract functions) in a BIM-enabled EPC project setting, the effect of the individual functions on EPC project performance was not identified. For instance, the contract that specified the right to audit for compliance while delivering BIM may impact perceived fairness (procedural fairness) positively for one party but may induce distrust for the other party. How this contract function translates into project performance is not clear. Future research on the model should investigate the perspectives of both contracting parties and identify ways to achieve optimal trust between parties during the development of BIM-related contracts. Additionally, industry norms and standard contract provisions, which may have implications for the model beyond the scope of this research, also require further investigation.

Although the study has successfully shown the mediating effects of interorganizational trust and distrust in the relationship between joint-contract functions and BIM-enabled EPC project performance, future studies should determine how contract functions influence trust among project stakeholders through a comprehensive social network analysis. Through investigating formal and informal collaborative relationships using social network analysis, researchers could assess the dynamic evolution of interorganizational trust among project participants during BIM-enabled project implementation (Lee et al. 2017).

Conclusions

This study has determined the direct and mediating effects of joint-contract functions and BIM-enabled EPC project performance through PLS-SEM. The research outcomes have demonstrated that relational trust has a positive influence on the relationship between joint-contract functions and EPC project performance. It also showed that, while calculative trust may not significantly mediate the relationship between joint-contract functions and EPC project performance, its impacts are more pronounced in terms of perceived fairness. This suggests that joint-contract functions may influence interorganizational trust for BIM-enabled EPC project performance improvement when fairness is perceived. Moreover, the study demonstrated that the calculative distrust influenced by the joint-contract functions may not necessarily have negative implications for project performance. In other words, calculative distrust arising from joint-contract functions may not be detrimental to EPC project performance and is an important element in BIM-enabled projects. The examinations of the effects of joint-contract functions on BIM-enabled EPC project performance and their mediating effects have provided valuable insights for relevant industries, showing mainly that

BIM can be implemented effectively within a traditional EPC contract setting. The current findings contribute to knowledge development of appropriate contract framing for BIM-enabled EPC project stakeholders, an area not discovered in the previous literature. However, for this complementary approach to be used effectively in EPC projects, certain changes should be made to contracts to influence interorganizational trust, distrust, and perceived fairness between owners and EPC contractors. This approach will maximize the potential for EPC project success.

Data Availability Statement

All data generated or analyzed during the study are included in the submitted article and supplemental data file.

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Table 1. Measurement of key constructs

No.	Variables/ Code	Reflective Measurement Items	Modified from Referred Sources
1	**Contractual Control (CON)**		
	CON_ 1	The contract specified right to audit for compliance with the creating, using and maintaining BIM.	Lumineau and Henderson (2012)
	CON_ 2	The contract stipulated damages against the party which failed to conform to the obligations of creating, using and maintaining BIM.	Lumineau and Henderson (2012)
	CON_ 3	The contract provided provisions for controlling and monitoring BIM deliverables.	Lumineau and Henderson (2012)
	CON_ 4	The contract specified resolution for nonconformance to the terms and conditions of creating, using and maintaining BIM.	Lumineau and Henderson (2012)
2	**Contractual Coordination (COR)**		
	COR_ 1	The contract delegated duties to create, use and maintain BIM.	Lumineau and Henderson (2012)
	COR_ 2	The contract provided operational coordination for parties to discuss the necessary adjustments that need to make on BIM upon completion of the model review.	Lumineau and Henderson (2012)

	COR_ 3	The contract provided strategic coordination for parties to sharpen the second-stage specific objectives of BIM development through mutual consultations after completion of the first-stage BIM development.	Lumineau and Henderson (2012)
	COR_ 4	The contract provided dispute resolution provisions to deal with the conflicts arising from developing, using and maintaining BIM.	Lumineau and Henderson (2012)
3	**Contingency Adaptability (COA)**		
	COA_ 1	The contract provided provisions that required revisions/updates of BIM in conjunction with the variations/changes to the works.	Wang et al. (2017)
	COA_ 2	The contract provided principles or guidelines for handling unforeseen circumstances arising from developing, using and maintaining BIM.	Wang et al. (2017)
	COA_ 3	The contract provided solutions for responding to various contingencies arising from developing, using and maintaining BIM.	Wang et al. (2017)
	COA_ 4	The contract specified procedures for changes made in BIM.	Quanji et al. (2016)
4	**Calculative Trust (CAL)**		
	CAL_ 1	Considering risks and rewards, we believed the other party would behave honestly in dealing with us.	Poppo et al. (2016)

	CAL_ 2	Taking into account the high cost of misconduct, we believed the other party would behave trustworthily in performing the works.	Poppo et al. (2016)
	CAL_ 3	We believed the other party would act professionally and competently in performing the works.	Poppo et al. (2016)
	CAL_ 4	We expected the relationship with the other party would continue for a long time.	Wu et al (2017)
5	**Relational Trust (REL)**		
	REL_ 1	Both of us were confident that our interests would be protected because we shared a common identity.	Poppo et al (2016)
	REL_ 2	We believed the other party would act effectively for us because we shared the same understanding of what matters.	Poppo et al (2016)
	REL_ 3	We believed the other party would be willing to share information with us given that both of us shared the common objectives.	Poppo et al (2016)
	REL_ 4	Both of us would be willing to look for a joint solution to a problem arising in the project because we shared the common objectives.	Poppo et al (2016)
6	**Calculative Distrust (DIS)**		

	DIS_ 1	We believed monitoring of vulnerabilities (e.g. potential leakage of valuable knowledge) would safeguard our interest in the project.	Lumineau (2017)
	DIS_ 2	We believed healthy suspicion of the other party would protect us against potential opportunism.	Lumineau (2017)
	DIS_ 3	We supported vigilance against the other party.	Lumineau (2017)
	DIS_ 4	We believed constructive scepticism of the other party enabled us to work more confidently in the project.	Lumineau (2017)
7	**Perceived Fairness (PF)**		
	PF_ 1	Our remuneration was commensurate with our ability, effort, input, and experience.	Lim and Loosemore (2017)
	PF_ 2	We were provided with adequate resources to execute our work effectively.	Lim and Loosemore (2017)
	PF_ 3	The risks that we were required to bear were equitable and commensurate with our capability to cope with them.	Lim and Loosemore (2017)
	PF_ 4	We were paid equitably for the job that we completed.	Lim and Loosemore (2017)
8	**Project Performance (PP)**		
	PP_ 1	In general, the project team members were very satisfied with their work.	Thompson et al (2007)
	PP_ 2		

	The project outcome added value to the business operations of our firm.	Thompson et al (2007)
PP_ 3	The rate of the project met the schedule as compared to other projects.	Thompson et al (2007)
PP_ 4	The rate of the project met the budget as compared to other projects.	Thompson et al (2007)
PP_ 5	The rate of the project met the quality of the produced work as compared to other projects.	Thompson et al (2007)
PP_ 6	The rate of the effectiveness of team members' interactions as compared to other projects.	Thompson et al (2007)
PP_ 7	The rate of the project met the health and safety expectations as compared to other projects.	Suprapto et al. (2016)

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Table 2. Results summary of reflective measurement models

Variables	Indicators	Outer Loadings	Cronbach alpha	Composite Reliability (CR)	AVE
Contractual Control (*CON*)	*CON_ 1*	0.801	0.823	0.883	0.653
	CON_ 3	0.841			
	CON_ 4	0.842			
Contractual Coordination (*COR*)	*COR_ 2*	0.864	0.831	0.888	0.665
	COR_ 3	0.821			
Contingency Adaptability (*COA*)	*COA_ 1*	0.818	0.857	0.903	0.699
	COA_ 2	0.834			
	COA_ 3	0.840			
	COA_ 4	0.852			
Joint Contract Functions (*FUNC*)	*CON_ 1*	0.672	0.927	0.937	0.556
	CON_ 3	0.766			
	CON_ 4	0.770			
	COR_ 2	0.779			
	COR_ 3	0.763			
	COA_ 1	0.785			
	COA_ 2	0.768			
	COA_ 3	0.754			
	COA_ 4	0.793			
Calculative Trust (*CAL*)	*CAL_ 1*	0.767	0.777	0.857	0.601
	CAL_ 2	0.779			
	CAL_ 3	0.843			

	CAL_ 4	0.704			
Relational Trust (*REL*)	*REL_ 1*	0.798	0.811	0.876	0.639
	REL_ 2	0.858			
	REL_ 3	0.801			
	REL_ 4	0.736			
Calculative Distrust (*DIS*)	*DIS_ 1*	0.793	0.745	0.824	0.540
	DIS_ 2	0.751			
	DIS_ 3	0.718			
	DIS_ 4	0.673			
Perceived Fairness (*PF*)	*PF_ 1*	0.734	0.795	0.867	0.620
	PF_ 2	0.819			
	PF_ 3	0.776			
	PF_ 4	0.818			
Project Performance (*PP*)	*PP_ 1*	0.729	0.840	0.879	0.509
	PP_ 2	0.686			
	PP_ 3	0.725			
	PP_ 4	0.708			
	PP_ 5	0.758			
	PP_ 6	0.735			
	PP_ 7	0.649			

Table 3. Heterotrait-Monotrait Ratio (HTMT)

	CAL	*COA*	*CON*	*COR*	*DIS*	*PF*	*PP*	*REL*
CAL								
COA	0.255							
CON	0.144	0.838						
COR	0.255	**0.950**	0.847					
DIS	0.257	0.285	0.248	0.269				
PF	0.472	0.377	0.295	0.291	0.317			
PP	0.510	0.255	0.166	0.233	0.196	0.694		
REL	0.859	0.379	0.219	0.392	0.352	0.536	0.536	

Table 4. Effect size f^2

	CAL	*DIS*	*PF*	*PP*	*REL*
CAL				0.030	
DIS				0.000	
FUNC	0.010	0.028	0.102	0.009	0.046
PF	0.127	0.048			0.165
PP					
REL				0.047	

Table 5. Direct effect, total effect and indirect effect of relevant paths

Hypothesis	Coeff.	T value	Significance level	p value	Confidence intervals Lower Bound (5%)	Confidence intervals Upper Bound (95%)
Direct effect						
H1: *FUNC -> PP*	0.090	1.414	ns	0.157	-0.013	0.196
Total effect						
H1: *FUNC -> PP*	0.227	3.215	***	0.001	0.117	0.349
Indirect effect						
H1: *FUNC -> PP*	0.136	3.970	***	0.000	0.087	0.199
H2: *FUNC -> CAL -> PP*	0.230	1.142	ns	0.253	-0.001	0.062
H3: *FUNC -> REL -> PP*	0.058	2.668	***	0.008	0.025	0.096
H4: *FUNC -> DIS -> PP*	0.001	0.083	ns	0.934	-0.019	0.022
H5: *FUNC -> PF -> CAL -> PP*	0.023	1.720	*	0.085	0.006	0.049
H6: *FUNC -> PF -> REL -> PP*	0.031	2.505	**	0.012	0.013	0.055
H7: *FUNC -> PF -> DIS -> PP*	0.000	0.081	ns	0.935	-0.006	0.010

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.

Table 6. Moderation effects of relevant paths

Path	Moderator	Coeff.	t value	Significance level	p value	Confidence Interval	
						Lower Bound (5%)	Upper Bound (95%)
FUNC -> DIS	Contract value	0.081	2.549	**	0.011	0.043	0.129
FUNC -> REL	Project location	-0.400	2.234	**	0.026	-0.072	0.635
FUNC -> PP	Project duration	0.251	2.406	**	0.017	0.108	0.400
FUNC -> DIS	Project duration	0.296	3.350	***	0.001	0.178	0.456