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Critical assessment of construction contract administration using fuzzy structural equation modeling

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Abstract

Purpose – This paper covers the development of a multidimensional contract administration performance model (CAPM) for construction projects. The proposed CAPM is intended to be used by the industry stakeholders to measure the construction contract administration (CCA) performance and identify the strengths and weaknesses of the CCA system for running or completed projects.

Design/methodology/approach – The research design follows a sequential mixed methodology of qualitative and quantitative data collection and analysis. In the first phase, contract administration indicators were collected from relevant literature. In the second phase, an online questionnaire was prepared, and data were collected and analyzed using the crisp value of fuzzy membership function, and structural equation modeling (SEM). The fuzzy set was chosen for this study due to the presence of uncertainty and fuzziness associated with the importance of several key indicators affecting the CCA performance. Finally, SEM was used to test and analyze interrelationships among constructs of CCA performance.

Findings – The data collected from 336 construction professionals worldwide through an online survey was utilized to develop the fuzzy structural equation model. The goodness-of-fit and reliability tests validated the model. The study concluded a significant correlation between CCA performance, CCA operational indicators, and the process groups.

Originality/value – The contribution of this paper to the existing knowledge is the development of a fuzzy structural equation model that serves as a measurement tool for the contract administration performance. This is the first quantitative structural equation model to capture contract administration performance. The model consists of 93 Construction Contract Administration(CCA) performance indicators categorized into 11 project management process groups namely: project governance and start-up; team management; communication and relationship management; quality and acceptance management; performance monitoring and reporting management; document and record management; financial management; changes and control management; claims and dispute resolution management; contract risk management and contract closeout management.

Keywords Fuzzy set, Structural equation model, Contract administration, Contract project management, Contract project success factor, Contract risk assessment

Paper type Research paper

1. Introduction

While projects are the core business of the construction industry, each project has its unique contract, which is a vehicle or a tool to assist and enable cooperation between parties (Puil and Weele, 2014). Each project requires proper construction contract administration (CCA)

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processes. The literature reveals that CA is one of the most serious challenges facing the project stakeholders (Niraula *et al.*, 2008), and effective CCA is getting increasing attention in the construction industry (El-adaway *et al.*, 2018). Likewise, several researchers emphasize the need for a better understanding and training on good administrative practices (Ahmed, 2015; Bartsiotas, 2014; Kayastha, 2014; Niraula *et al.*, 2008; Surajbali, 2016).

This paper covers the development of a contract administration performance model (CAPM) and develops an overall performance index at the project level. The proposed CAPM categorizes 93 CCA key factors (indicators) affecting the contract administration into 11 associated process groups (constructs). To suggest the association between the indicators and first-order constructs, confirmatory factor analysis (CFA) is conducted. On the other hand, the overall construction contract administration performance index (CCAPI) is predicted as a second-order reflective construct that is linked to the 11 process groups by using a structural model.

The contribution of this paper to the existing knowledge is that it develops the first fuzzy structural equation model in overall contract performance measurement to the authors' knowledge. First, it emphasizes the key indicators required to measure the CCA performance for the general construction projects. Second, the 11 dimensions of the proposed model link the contract administration function to the project management process groups. Third, the model can track the underperformance area to establish improvement programs for enhancing the CCA performance. Fourth, academia can simulate the methodology implemented within the study for data analysis and validation in other research areas. In practice, the proposed CAPM may be used by the construction industry professionals to measure the CCA performance and identify the strengths and weaknesses of the CCA system for running or completed projects. Also, the model serves as a benchmarking tool to compare contract administration processes among different projects to achieve the best contract management practices.

2. Review of literature

Contract administration is a process of ensuring the proper performance of each party in meeting their stipulated contractual obligations until the contract is either closedout or terminated (Ofori, 2014). It can be seen as the necessary paperwork associated with a construction project by a third party assigned with predetermined roles and responsibilities to act on behalf of the employer. It is a key requisite for a successful contract that covering the formal governance of the post-award phase, approvals of changes, overseeing daily construction activities, testing and commissioning, handing over, and defects rectification works (Niraula *et al.*, 2008; Ofori, 2014). Since contracts are not self-enforcing, contract administration is important to address conflicts on time (Puil and Weele, 2014), reduce disputes (Abotaleb and El-adaway 2017; El-adaway *et al.*, 2018), control changes (Islam *et al.*, 2019), maintain relevant records (Iyer and Jha, 2005), resolve discrepancies or inconsistencies among the several contract documents (Hamie and Abdul-Malak, 2018), safeguard entities' rights (Oluka and Basheka, 2014) and reduce risks (Joyce, 2014). Not only those but, it is important to monitor and control contract implementation, managing challenges associated with the construction industry, ensure the achievement of the project objectives, ensure project compliance, manage roles and responsibility, and protect the financial interest of the key stakeholders.

In spite of the importance of CCA function, a proper CCA is yet recognized in several projects, and numerous issues are being referred to poor CCA procedures (Park and Kim, 2018). CCA process is one of the major causes of disputes in construction projects (El-adaway *et al.*, 2018) and is a concern to construction professionals worldwide (Arcadis, 2018). The challenges associated with CCA performance include unresponsive acts by CCA staff

(Ssegawa, 2008), insufficiency and incompetency of staff (Puil and Weele, 2014; Surajbali, 2016), lack of adequate policies and procedures (Surajbali, 2016), inefficient monitoring of the contract (Surajbali, 2016), ineffective decision-making (Puil and Weele, 2014), frequent changes in design and specifications of major equipment (Islam *et al.*, 2019), payments problems (Puil and Weele, 2014; Rendon, 2010; Ssegawa, 2008), communication issues (Barakat *et al.*, 2018), timeline constraints (Joyce, 2014; Rendon, 2010), and corruptions (Joyce, 2014). The adverse impact of the poor CA is recognized through several terminated contracts (Yap, 2013), increased rate of claims, reduced liquidity in the markets and excessive use of variations (Okere, 2012).

2.1 Poor contract administration

Unfortunately, the literature reveals several aspects of poor CCA, failures to perform, and misunderstanding of roles and responsibilities by the CCA team. Some examples of such aspects are poor planning (Alzara *et al.*, 2016; Memon and Rahman, 2013), lack of systems, procedures and guidance (Surajbali, 2016), delay in handing over sites to the contractor (Alzara *et al.*, 2016). Also, the CCA team may have lack of understanding of procurement processes (Ahmed, 2015; Surajbali, 2016), unclear roles and responsibilities (Surajbali, 2016), and lack of training with relevant knowledge and lack of skilled team (Ahmed, 2015; Alzara *et al.*, 2016; Surajbali, 2016). During the performance of a contract, poor communication across the organizations, lack of monitoring of contract-related activities, and unclear contract performance measures are frequently realized (Surajbali, 2016). Furthermore, poor performance is also reported in terms of slow response to contractor's inquiries, delay in issuing further information, delay in approvals, and inadequate supervision (Alzara *et al.*, 2016; Memon and Rahman, 2013; Surajbali, 2016). Not only this but also, contractors are suffering from improper payment procedures (Abotaleb and El-adaway 2017; Okere, 2012; Surajbali, 2016), delayed payments (Ahmed, 2015; Alzara *et al.*, 2016; Joyce, 2014; Memon and Rahman, 2013; Okere, 2012), and unavailable funds (Okere, 2012). Thus far, insufficient use of information and communication technology (ICT) (Ahmed, 2015; Joyce, 2014; Okere, 2012; Surajbali, 2016), and poor record-keeping (Ahmed, 2015) are tracked within the record management area. The change management area is impacted by poor change management (Alzara *et al.*, 2016; Park and Kim, 2018). Similarly, the claim management area is affected by a lack of effective claim procedures (Alzara *et al.*, 2016). Within the risk management area, unclear risk allocation and the risk of changes due to late discovery of design errors are also tracked in construction projects (Shen *et al.*, 2017; Yap, 2013). At the closeout phase, slow response towards verification of completed works (Alzara *et al.*, 2016), late release of retention (Abotaleb and El-adaway 2017), and valuation of final account (Abotaleb and El-adaway 2017) are few examples of the most problematic area.

2.2 Contract administration models and frameworks

Academia and the construction industry professionals continue to suggest models and frameworks ensuring proper contract administration. For example, Garrett and Rendon (2005) developed a maturity assessment tool to assess the organization's capability and improve the level of performance. The maturity model covered only 2 dimensions and 21 activities related to CCA without providing any quantified analysis for their significance. Okere (2012) established the association between contract administration practices and performance of the general contractors on governmental infrastructure projects in the United States. The author attempted to correlate the contract administration performance and management attitude towards contract risks, provisions for mitigating contract risks, the stability of scope definition, contract administration infrastructure, resource allocation strategy, and competency of contract administrators. The study utilized Pearson's correlation and multiple regression to correlate the 6 dimensions to 62 activities and revealed a significant correlation between CCA performance management and resource allocation strategy but could not correlate other dimensions. Bartsiotas (2014) provided a structured assessment model to enable United Nations (UN) procurement organizations to recognize its development level in post-contract management processes and to highlight the contract management strengths and weaknesses by using a comparative study. The study concluded the good administration practices, the lessons learned, improvement areas for the sake of improving the coherence of the overall procurement system. Joyce (2014), proposed a conceptual framework comprises of 5 dimensions (i.e. contractor monitoring and acceptance management, managing the contractor relationship, contract administration, dispute resolution, and contract closure) and 32 operational indicators as dependent variables. By using a Linear Regression and ANOVA, the findings of this study indicated that effective contract management has a positive effect on operational performance. The key recommendations were steady training, suitable information systems in addition to improved flexibility, and improved risk management for improving the effectiveness of CCA. Appiah Kubi (2015), proposed a model for contract administration practices during the post-award phase in Ghana. By using the relative importance index (RII), the author ranked 72 contract administration activities within 10 CCA dimensions that can be applied to construction projects. The study emphasized that the post-award process groups need improvement by developing policies, rules, and procedures, and use an integrated and multifunctional team approach. Surajbali (2016), investigated the post-award contract administration key activities within the general procurement framework of South Africa. The author categorized the challenges facing contract administration and then established a framework for managing the contract with 9 dimensions. Contrary to other models/frameworks, this study stopped at the level of the dimensions without having any statistical analysis for the impact of each dimension. The study concluded the need for a suitable contract management process flow and suitable organizational structure. Similar frameworks and models were identified in the area of general procurement and contract administration/ management by Crampton (2010) for the Transport Agency in New Zealand, Kayastha (2014) for hydropower projects in Nepal, Moore (1996) for marine corps in the USA, Oluka and Basheka (2014) for effective procurement contract management in Uganda, Park and Kim (2018) for contract management capabilities in overseas construction projects, and Solis (2016) for the Dutch wastewater industry. The previous studies were formulated to serve a certain geographical area or a specific type of project with simple statistical techniques or stopped at the qualification of indicators.

3. Point of departure

The poor performance of CCA and its direct impact on the project necessitates the need to establish a reliable and comprehensive performance assessment model for construction contract administration. Having considered the reviewed literature, the authors argue the non-availability of such types of measurement tools due to a limited number of indicators and constructs within the same model and use of simple statistical techniques to identify the indicators' significance. This study differs from other studies in the literature by gathering a significant number of indicators and constructs representing the global view of construction contract administration at the project level within one model and developing a multidimensional fuzzy structural equation model that serves as a contract administration performance measurement tool. As demonstrated in the literature, this is the first utilization of fuzzy structural equation modeling to model the contract administration performance to the authors' knowledge.

4. The proposed construction contract administration model

This paper covers the development of a multidimensional construction contract administration performance model (CAPM). The CAPM is a designed approach to administer a contract and assist in identifying the activities required for ensuring the successful completion of a project. A comprehensive literature review is made to determine 93 key factors (indicators) and 11 project management process groups (constructs) related to contract administration performance. The process groups are G01-project governance and start-up, G02-contract administration team management, G03-communication and relationship management, G04-quality and acceptance management, G05-performance monitoring and reporting management, G06-document and record management, G07-financial management, G08-changes and changes control management, G09-claims and disputes resolution management, G10-contract risk management, and G11- contract closeout management. The 11 constructs and their related references are presented in Table 1.

Each construct includes specific operational indicators related to that construct so as to measure its performance and covers the post-awarding phase of the construction project. The constructs G01 to G11 contain 15, 6, 11, 10, 10, 4, 7, 5, 8, 4, and 13 indicators, respectively. The 93 indicators cover obligations of CCA function under the general conditions of the contract, the CCA team responsibilities under the professional service agreement, the best practices, success factors, and strategies to avoid consequences of poor contract administration. The G02-team management, G06-document and record management, and G10-contract risk management process groups serve the other eight processes and are supporting the CCA function by providing the required qualified resources, a system for managing the project documentation and records, and system to minimize threats of risk. G03-communication and relationship management, G05-performance monitoring and reporting management, G07-financial management, G08-changes and changes control management, and G09-claims and disputes resolution management process groups are representing the monitoring and control groups of the project management in addition to their attributes as a core competency of CCA. G01-governance and start-up management, G04-quality and acceptance management, and G11-contract closeout management process groups represent planning, executing, and closing process groups of project management and further receive and provide data to the core competency process groups. In practice, there are interactions among the different constructs to achieve the overall construction administration function. For example, the inspection requests generated from the G04-quality and acceptance management provides an input to the payment process (G07-financial management) and progress of works (G05-performance monitoring and reporting). Not to say, each construct involves a huge effort and may occur in one or more phases of the project. Figure 1 *summarizes the 93 CCA indicators (key activities*) related to the 11 constructs.

5. Research methodology

The research design follows a sequential mixed methodology of qualitative and quantitative data collection and analysis. In the first phase, contract administration indicators were collected from relevant literature coupled with face-to-face semi-structured interviews with one academic and three industry experts (with over 25 years of experience in CCA and construction management). In the second phase, an online questionnaire was prepared, and data collected and analyzed using a fuzzy Structural Equation Modelling (F-SEM).

In 1965, Fuzzy set/logic was developed by Zadeh to gives the human reasoning process a mathematical precision and captures vague conditions and subjective information with a descriptive language (Singhaputtangkul and Zhao, 2016). It is a collection of mathematical principles for the illustration of information based on degrees of membership. It was applied successfully on several construction management topics (Chan *et al.*, 2009). Since a long time,

Table 1.
Dimensions of contract administration model (CAPM) and their relevant references

Code	Dimension (construct)	Appiah Kubi (2015)	Bartsiotas (2014)	Crampton (2010)	Doloi (2013)	Joyce (2014)	Kayastha (2014)	Miller *et al.* (2012)	Moore (1996)	Mwanaumo *et al.* (2017)	Okere (2012)	Oluka and Basheka (2014)	Park and kim (2018)	Solis (2016)	Taccad (1999)
G01	Project governance and start-up	√	√	√			√	√		√				√	
G02	Contract administration team management	√	√	√	√						√	√			
G03	Communication and relationship management			√	√	√		√	√			√		√	
G04	Quality and acceptance management	√	√	√	√		√		√	√					√
G05	Performance monitoring and reporting management	√	√	√	√	√		√	√	√				√	√
G06	Document and record management	√	√											√	

(*continued*)

Code	Dimension (construct)	Appiah Kubi (2015)	Bartsiotas (2014)	Crampton (2010)	Doloi (2013)	Joyce (2014)	Kayastha (2014)	Miller *et al.* (2012)	Moore (1996)	Mwanaumo *et al.* (2017)	Okere (2012)	Oluka and Basheka (2014)	Park and kim (2018)	Solis (2016)	Taccad (1999)
G07	Financial management	√	√	√				√		√		√	√		√
G08	Changes and changes control management	√	√	√			√		√				√	√	√
G09	Claims and disputes resolution management	√	√	√		√	√			√			√		√
G10	Contract risk management	√	√	√	√						√	√		√	
G11	Contract closeout management	√	√	√		√				√			√	√	√

Table 1.

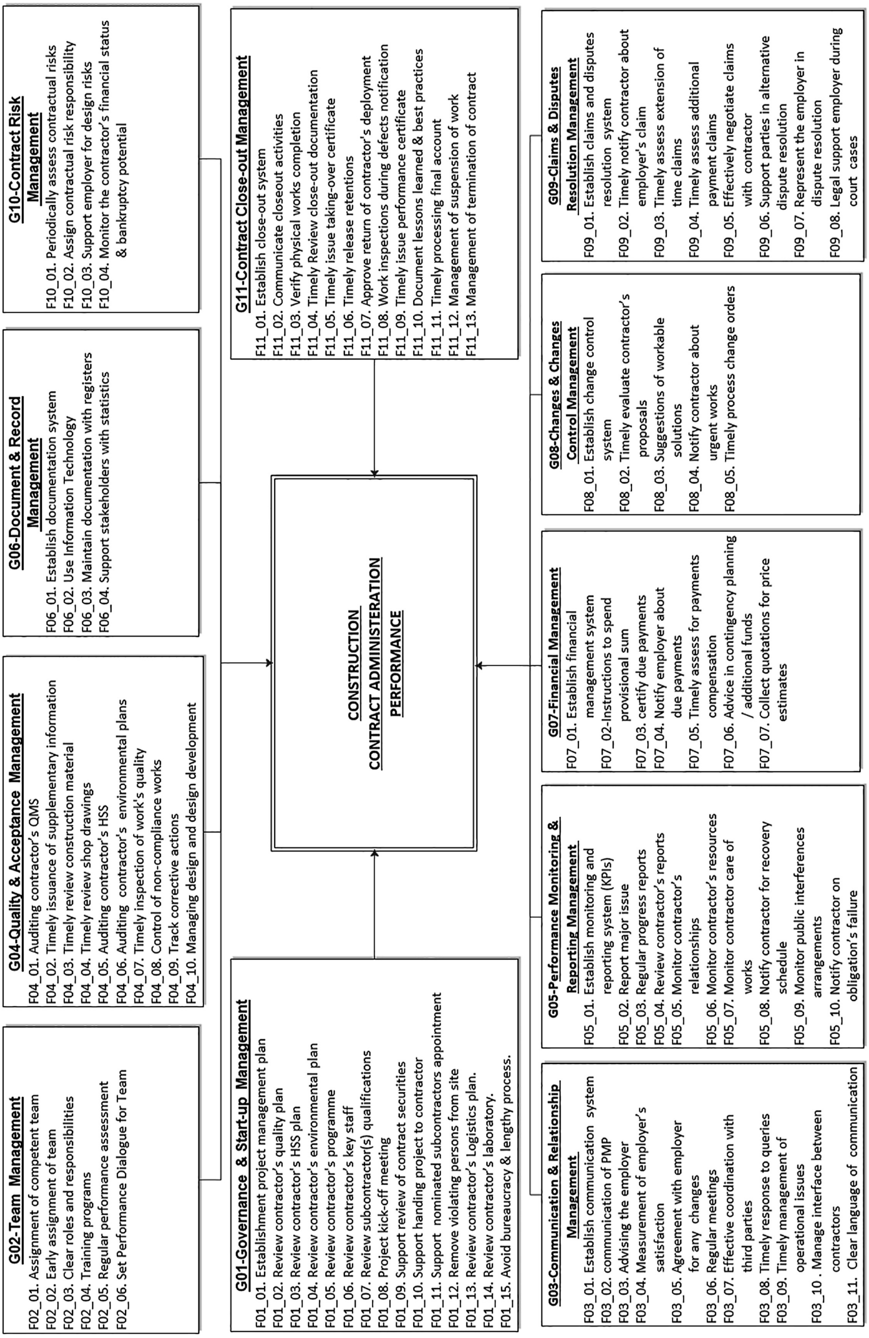

Figure 1.
Factors affecting contract administration performance

fuzzy set theory (FST) has been used for construction management applications such as tender evaluation with multiple criteria and many decision making parties, bidding margin, evaluating alternative construction technology, project control and scheduling, cash flow analysis, and the association between the final project outcomes and the behavior of the project managers (Ameyaw *et al.*, 2016). It is suitable for the construction industry because the construction industry is unique in characteristics and lack of historical data in some areas (Chan *et al.*, 2009). Therefore, FST was chosen for this study due to a lack of quantitative data on the subject, the presence of uncertainty, and fuzziness associated with the importance of several indicators affecting the CCA performance.

Structural Equation Modeling (SEM) is a multivariate statistical technique to estimate constructs and assess hypotheses testing through a confirmatory approach based on empirical data. According to Ozdemir (2015) and Xiong *et al.* (2015), SEM is more powerful than other multivariate analysis techniques to evaluate the constructs as the method can: (1) allow studying non-quantifiable variables using constructs underlying the indicators; (2) provide adequate accuracy for hypothesis testing and evaluate an unlimited number of hypotheses; (3) examine the interrelationships between constructs; (4) perform simultaneously multiple regression equations analysis; (5) analyze a massive number of variables having different relationships with several complex models; (6) consider the impacts of ill-measured data through measurement errors of indicators; and (7) support validity and reliability tests with several fit indices; (8) perform comparisons between groups with a more holistic model than traditional statically analysis techniques. The descriptive and exploratory nature of other multivariable analysis techniques makes SEM the most applicable method for model testing. Xiong *et al.* (2015) carried out a review of applications of the structural equation modeling in construction researches between the period of 1998–2012 for the top construction research journals and found broad implementation, acceleration, and acceptance for SEM over time. Molenaar *et al.* (2000) performed one of the early implementations of SEM in the construction area. Molenaar illustrated the ability of structural equation model analysis to quantify factors affecting contract disputes between contractors and owners (disputes potential index). Also, SEM showed its strength to present the interaction of the variables over the logistic regression modeling. Gunduz *et al.* (2017), used fuzzy SEM to empirically validate the theoretical model and develop a multidimensional safety performance model in construction sites. The study concluded the ability of SEM to model the safety performance on construction sites. Shen *et al.* (2017), formulated a short structural equation model for causes of contractors' claims in EPC projects with three constructs, namely, external risk, client organizational behavior, and project definitions in the contract. Memon and Rahman (2013) adopted a structural equation modeling (SEM) approach to measure the impact of cost overrun factors on project cost in construction projects in Bahrain and concluded that contract administration and project management-related factors are the highest impact factors causing cost overrun.

Thus, integrated fuzzy structural equation modeling (F-SEM) is used to test and analyze interrelationships among indicators and constructs of the CAPM model. The SEM model is developed using AMOS 24 SEM package.

6. Questionnaire administration

The questionnaire contained three parts, namely: (1) an introduction regarding the research, (2) ten anonymous questions about respondents' demographics, and (3) questions concerning the importance of the 93 CAPM indicators and the 11 CAPM constructs. Respondents were requested to rate their perspectives on the importance of the CCA indicators and constructs. Of the respondents, 366 rated the significance of factors on a 5-point Likert scale from "Not at all important" to "Extremely Important," while only 336 responses were used for final analysis due to unengaged responses and outliers.

6.1 Demographics of respondents

The respondents have a varied level of working experience in the construction industry. The participants with less than five years of experience were 25 (7.4 per cent), 6–10 years 49 (14.6 per cent), 11–15 years 57 (17 per cent), 16–20 years 69 (20.5 per cent), 21–25 years 66 (19.6 per cent) and more than 25 years 70 (20.8 per cent) respectively. 249 (74.1 per cent) of the respondents had a professional registration as either authority registered, syndicate membership, chartered or professional engineers. More than half of the respondents, 181 (53.9 per cent), had contract management training. Among the respondents, the private sector workers were 187 (55.7 per cent), public sector workers were 125 (37.2 per cent), and mixed sector workers were 24 (7.1 per cent). Moreover, the respondents were categorized according to their types of organizations, such as consultants and designers 164 (48.8 per cent), employers 49 (14.6 per cent), contractors 117 (34.8 per cent), and mixed employments 6 (1.8 per cent). The data was collected from experts worldwide.

6.2 Sample size

There is no agreement on the desired sample size for SEM models. For a small number of items and well-behaved data, Bagozzi and Yi (2011) argued that a sample size below 100 might be expressive, but the preferred sample size should be above 200. In his review, Xiong *et al.* (2015) analyzed the sample size for 84 literature papers concerning SEM implementation in construction and stated that a sample size of less than 200 had been used in 77.4 per cent of the studies (65 of 84). This shows that this study has enough data to develop a model.

6.3 Fuzzy operations

Commonly, the implantation of FST starts with selecting the linguistic variables to be used in data collection (in this case, the Likert scale of the questionnaire), determining fuzzy membership function values associated with the input variables, which is followed by selecting the aggregation and defuzzification methods. The linguistic variable means linguistic expressions rather than numerical values (Ozdemir, 2015), and each linguistic variable can be converted into a linguistic value in which each value is expressed as a membership function. A 5 or 7 point Likert scale appears to be the most common scale in the literature (Dawes, 2008), and the 5-point scale is frequently used in similar management areas (Joyce, 2014; Ozdemir, 2015). Accordingly, this study adopts 5-point scale, and the linguistic variables are defined as: (1) not at all important (NI), (2) slightly important (SI), (3) moderately important (MI), (4) very important (VI), and (5) extremely important (EI) and the practitioners are requested to rate the importance of factors on CCA performance according to the linguistic variable.

In the fuzzy set, the triangular shapes are the mostly employed form of membership function to quantify the qualitative information (Singhaputtangkul and Zhao, 2016). In this study, the triangular membership function proposed by Gunduz *et al.* (2017) to assess construction safety performance and establish a construction site safety performance index is selected, as shown in Figure 2. The Figure contains 5 triangles representing the membership functions associated with the 5-point Likert scale. The employed functions are: (NI = [0.0, 0.0, 0.3]), (SI = [0.0, 0.3.0, 0.5.0]), (MI = [0.2, 0.5, 0.8]), (VI = [0.5, 0.7, 1.0]), and (EI = [0.7, 1.0, 1.0]).

The methodology used by Gunduz *et al.* (2017), Ozdemir (2015), and Shyi (1997) is then utilized to transfer the membership functions into hard numbers (crisp values). According to

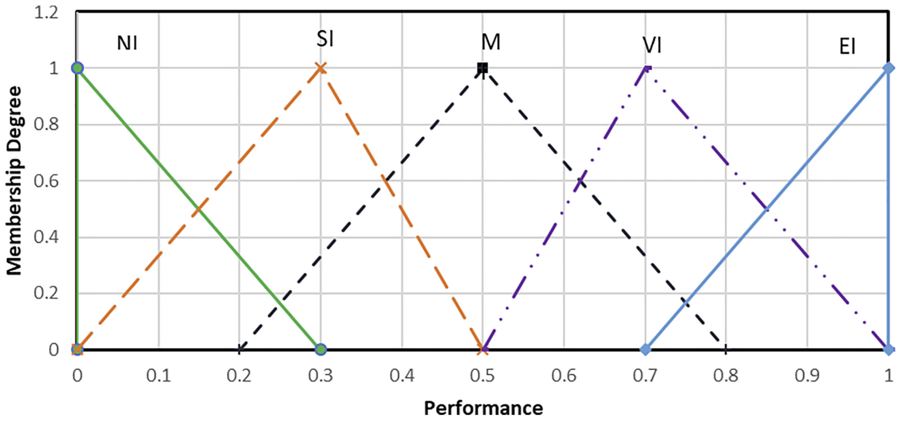

Figure 2.
Membership function

Shyi (1997), the defuzzification method of trapezoidal fuzzy numbers M (a, b, c and d) can be defuzzified by a value (e), which represents the center of gravity of the shape (i.e. (b−a)/2 + (e − b) = (c − e) + (d − c)/2, thus e = (a + b + c + d)/4). As triangle is a special case of the trapezoidal shape (i.e. c − b = 0), and therefore, e = (a + 2b + d)/4. Figure 3 shows the defuzzification method of trapezoidal fuzzy numbers.

For the proposed membership function and the associated fuzzy numbers, the defuzzified (crisp) values are shown in Table 2 as a result of deploying the center of the area method.

6.4 Data treatment

The design of the questionnaire did not allow for missing values by making all fields compulsory. The rating of the constructs was added to the end of the questionnaire survey in order to examine the unengaged (non-serious) responses and ensure the quality of responses. The researchers established a criterion to ascertain that the response shall be considered as an unengaged if the rated and calculated responses are deviated by more than one point of the scale (20 per cent) from the average rating of indicators within the same construct. Outliers were examined by comparing whether the respondent's input is in contrast with others through Mahalanobis distances (Hair *et al.*, 2014) using IBM Statistical Package for Social

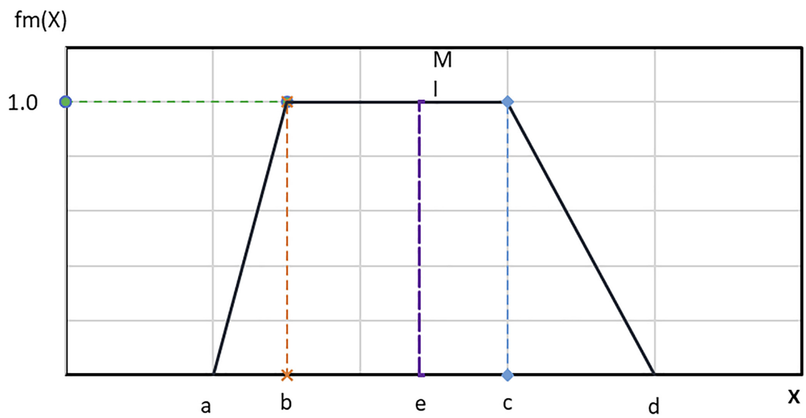

Figure 3.
Defuzzification of a trapezoidal fuzzy number M

Sciences (SPSS) multiple regression analysis. The 366 questionnaire responses were dropped to 336 responses due to 6 unengaged responses and 24 outliers.

7. The structural equation model

This paper uses a two-stage method to develop a structural model. The confirmatory factor analyses (CFA) and the structural model are used to investigate the relationships among constructs of CAPM and evaluate the reliability and validity of the proposed model. Bootstrapping the Maximum Likelihood (ML) estimation method is utilized to measure the structural paths and factor loadings (Byrne, 2010).

7.1 Model specification, identification, and estimation

The model specification sets a conceptual model comprised of the hypothesized relationships (theory) and establishing the associated equations. The model identification ensures that the specified model has a unique numerical solution, while model estimation means the selection of an appropriate estimation method to identify the model parameters. To suggest the association between the indicators and first-order latent constructs, CFA is conducted for the proposed CAPM model. The measurement model comprises of 93 indicators categorized into 11 first-order latent constructs, as shown in Figure 4.

On the other hand, to predict the relationship between first-order and second-order constructs, the structural model is established. The structural model comprises of 11 first-order latent constructs (G01 to G11) linked to a reflective second-order construct (so-called *construction contract administration performance index* (CCAPI)). The CAPM model suggests a positive relationship between the 11 first-order constructs and the CCAPI. Based on those assumptions, the study establishes two main hypotheses, and the first hypothesis is further subdivided into 11 sub-hypotheses. The study's main hypotheses are:

H1. Each construct has a positive influence on CCAPI.

H2. The model consisting of the 11 first-order constructs aggregates their effects on CCA performance.

7.2 The goodness of fit indices

Goodness-of-fit (GOF) indices are essential for model improvement and to show how good a fit the items are in measuring their respective latent constructs. Literature reveals the availability of several groups for model fit assessment (Xiong *et al.*, 2015) but without any consensus on the best indices. To assess the model fit, Hu and Bentler (1999) and Ping (2004) proposed to rely on Relative Chi-Square ($\chi 2$/df), Comparative Fit Index(CFI), and Root Mean Square Error of Approximation (RMSEA). The following indices were employed to assess the model-fit for this paper.

Relative chi-square ($\chi 2/df$): Contrary to the no-agreement on the proper overall goodness-of-fit index for evaluating a model, the $\chi 2$ statistic can be considered as a fundamental

Table 2.
Linguistic term, fuzzy number and crisp value of the membership function

Number	Linguistic term	Fuzzy number	Crisp value
1.	Not at all important (NI)	(0.0, 0.0, 0.0, 0.3)	0.075
2.	Slightly important (SI)	(0.0, 0.3, 0.3, 0.5)	0.275
3.	Moderately important (MI)	(0.2, 0.5, 0.5, 0.8)	0.500
4.	Very important (VI)	(0.5, 0.7, 0.7, 1.0)	0.725
5.	Extremely important (EI)	(0.7, 1.0, 1.0, 1.0)	0.925

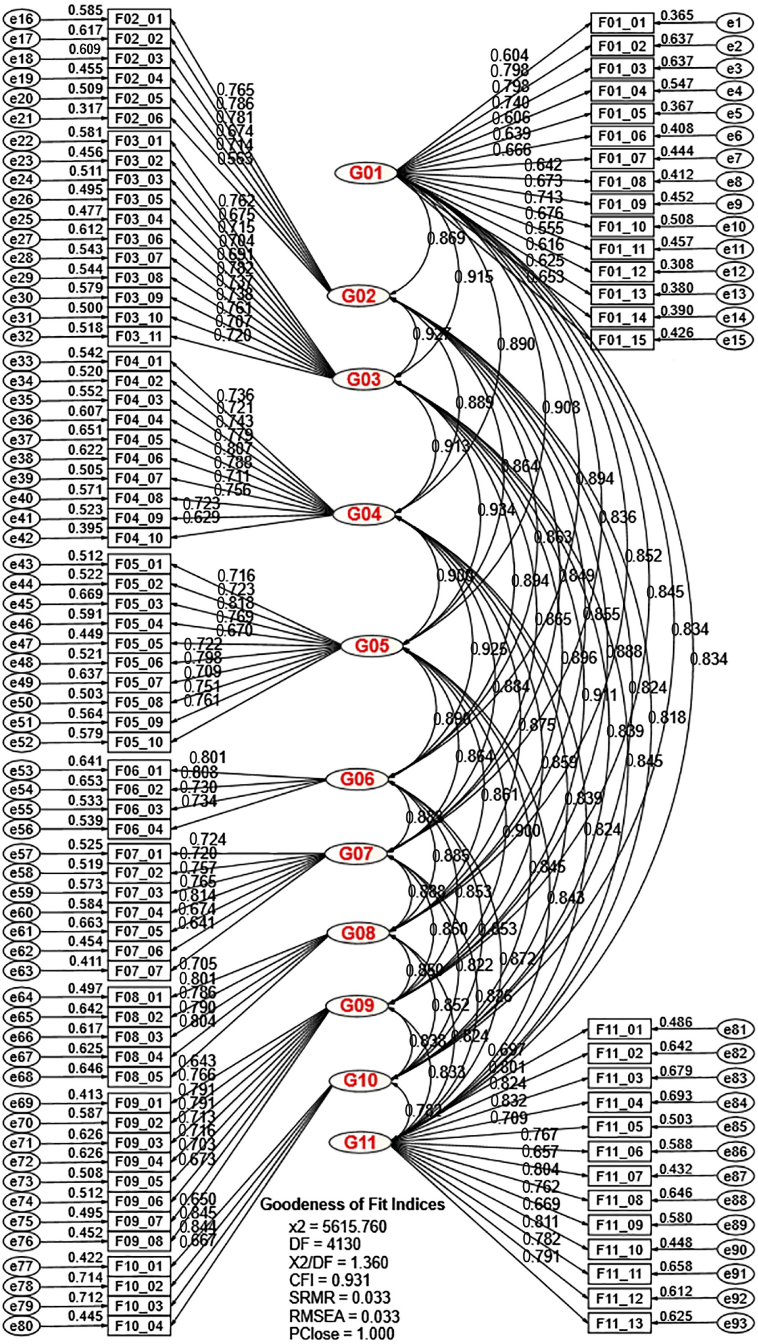

Figure 4.
confirmatory factor analysis for CAPM–standardized estimates

measure indicating the degree of discrepancy between the implied and sample covariance matrices (Bagozzi and Yi, 2011; Ping, 2004). A significant value of the $\chi 2$ test means that there is a substantial discrepancy between the model and data. Adjusted Chi-square($\chi 2$/df) with a value from one to three (Hair *et al.*, 2014; Xiong *et al.*, 2015) is used for a preferred fit.

Comparative fit index (CFI): It is an incremental fit index that compares the hypothesized model with a baseline model to check that the model fits the sample data better than the independent model. CFI values are ranging from 0 to 1, with a cut off value of 0.92 for good model fit (Hair *et al.*, 2014).

Root mean square error of approximation (RMSEA): This examines the average divergence between observed and predicted covariances and gives an absolute amount for the covariance residuals compared to the saturated model. RMSEA indicates the "badness-of-fit" index with an acceptable value ranging between 0.05 and 0.1 (Byrne, 2010), but an amount of less than 0.08 is considered a reasonable fit (Hair *et al.*, 2014). The null hypothesis probability of RMSEA to be close to 0.05 is tested by a one-sided test called (PClose). Thus, the PClose value more than 0.05 concludes that the model fit is "close." The Standardized Root Mean Square Residual (SRMR) is another absolute measure of fit representing the average difference between the observed and predicted correlations. A perfect fit is attained for SRMR value of zero and suggested a value below 0.08 is a good fit (Hu and Bentler, 1999).

As shown in Table 3, the CFA confirms that this measurement model has a good fit.

The results reveal that $\chi 2$/df value of 1.36 is below 3.00, as suggested by (Hair *et al.*, 2014). CFI is reported with a value of 0.931, which is above an acceptable fit of 0.90 (Hu and Bentler, 1999). SRMR and RMSEA show values of 0.033, which is below 0.08, and the PClose value is 1.000(>0.05). Bollen-Stine probability (p-value) is used to assess the probability of the model fit for the non-normal data. A Bollen-Stine bootstrap p-value of 0.225 is obtained using a conventional significance level of 0.05. Thus, it concludes that the CFA model achieves the requirement of the goodness of fit.

7.3 Evaluation of the reliability and validity of the measurement model

Upon selection of the appropriate estimation method, the CFA model is needed to be evaluated for reliability and validity before demonstrating the structural model. Different reliability and validity testes are suggested to substantiate the consistency of data with the hypothesized constructs. The reliability process comprises the internal consistency of constructs, which is further measured through individual item/indicator reliability (Cronbach's Alpha test) and unidimensionality. The validity process encompasses both convergent and discriminant validity tests. Construct validity is essential for testing of the reliable model and development of the theory (Xiong *et al.*, 2015).

Cronbach's alpha (α) reliability test is conducted to evaluate the reliability of a questionnaire for each indicator using the SPSS v25 package, which is utilized to assess the

Table 3. Examine the goodness of fit indices of the measurement model

Measure	Estimate	Threshold	Interpretation
$\chi 2$	5615.76	–	–
Df	4130	–	–
$\chi 2$/df	1.360	Between 1 and 3	Excellent
CFI	0.931	>0.90	Acceptable
SRMR	0.033	<0.08	Excellent
RMSEA	0.033	<0.06	Excellent
PClose	1.000	>0.05	Excellent
p-value (ML)	0.000	>0.05	
p-value (Bollen-Stine)	0.225	>0.05	

consistency of the entire scale with minimum cut off value 0.7 (Hair *et al.*, 2014). Table 4 shows the results of the reliability analysis for all variables and constructs in this paper.

All alpha values are more than 0.839. Therefore, the input of respondents is considered to be consistent and reliable for further analysis, and the set of indicators represents a single construct. The unidimensional assessment is performed through standardized factor loadings (SFL). Figure 4 shows that SFL of indicators are above the threshold of 0.5 (Hair *et al.*, 2014) and are positive numbers. Thus, the CAPM measurement model achieves this criterion of unidimensionality.

7.4 Testing convergent validity

Convergent validity (CV) tests that all indicators within a construct are correlated only to this construct. CV is satisfactory if all factor loadings of a construct are more than 0.5 (Hair *et al.*, 2014), the significance of regression weight is less than 0.05 (Zahoor *et al.*, 2017), the Average Variance Extracted (AVE) value is 0.50 or higher (Xiong *et al.*, 2015), and the composite reliability(CR) is higher than 0.7 (Hair *et al.*, 2014). AVE is a measure of the amount of variance that is captured by a construct to indicate convergence and is equal to the average of all squared factor loadings as shown in Eqn 1 (Hair *et al.*, 2014) while CR is computed from the squared sum of factor loadings (Li) for each construct and the sum of the error variance terms for a construct (ei) as shown in Eqn 2:

$$\mathrm{AVE} = \frac{\sum_{i=1}^{n} L_i^2}{n} \tag{1}$$

$$\mathrm{CR} = \frac{\left(\sum_{i=1}^{n} L_i\right)^2}{\left(\sum_{i=1}^{n} L_i\right)^2 + \sum_{i=1}^{n} e_i} \tag{2}$$

Where, Li = SFL; i = number of items; n = total no of items; and ei = error variance terms for a construct i.

According to Malhotra and Birks (2006), AVE is a stricter measure than CR, and the researcher may conclude that convergent validity is adequate by CR alone. Figure 4 shows that all factor loadings are higher than 0.5, and the significance of regression weight is less than 0.05. Therefore, satisfactory convergent validity is attained (Xiong *et al.*, 2015; Zahoor *et al.*, 2017). Also, the results reveal that all constructs have a CR value of more than 0.70 (range 0.841–0.948), the minimum of AVE value is 0.515 (above 0.50) except for construct number G01 as indicated in Table 4.

Group	No of items	Cronbach's alpha	Composite reliability (CR)	Average variance extracted (AVE)
G1	15	0.921	0.924	0.449
G2	6	0.857	0.863	0.515
G3	11	0.924	0.925	0.529
G4	10	0.923	0.924	0.549
G5	10	0.924	0.925	0.555
G6	4	0.851	0.853	0.592
G7	5	0.884	0.888	0.533
G8	8	0.896	0.884	0.605
G9	8	0.896	0.899	0.527
G10	4	0.839	0.841	0.573
G11	13	0.947	0.948	0.584
Overall	93	0.988	0.924	0.449

Table 4. Cronbach's alpha , composite reliability and average variance extracted coefficients of the latent variables

Thus, the results indicate the internal consistency of the construct and reliability of the model (Malhotra and Birks, 2006) and SFL, CR, and AVE values satisfy convergent validity criteria.

7.5 The CAPM structural model

The outcome from the measurement model demonstrates that it is well fit based on threshold values for the goodness of fit (GOF), reliability, and validity. Therefore, indicators represent and measure their respective latent constructs. The results of the structural model are shown in Table 5. The results reveal that $\chi 2$/df value of 1.365 is below threshold 3.0 suggested by (Hair *et al.*, 2014). CFI is reported with a value of 0.930, which is above 0.90. The SRMR and RMSEA values (0.033 and 0.033) are below 0.08, and the PClose value (1.000) is above the cut off value of 0.05. Thus, it concludes that the structural model achieves the requirement of the goodness of fit.

For the structural model, percent of variance explained (R^2) is the most important output that reflects the strong relationship (correlation level of importance) among second-order constructs and the first-order constructs by the model. Referring to Table 6, the SFL values are higher than 0.5 (Hair *et al.*, 2014; Xiong *et al.*, 2015), the significance of regression weights are less than 0.05 (Zahoor *et al.*, 2017), and the minimum value of R^2 is 0.787, which correlates the CCAPI to G011. Thus, the positive contributions of the 11 constructs are significant, and the theory that the construction contract administration performance is reflected by the eleven first-order constructs is well supported.

Figure 5 shows the significance of the main construct on every construct in the model from the regression path coefficient.

Table 5.
Goodness of fit indices for CAPM measurement model

Measure	Estimate	Threshold	Interpretation
$\chi 2$	5699.299	–	–
Df	4174	–	–
$\chi 2$/Df	1.365	Between 1 and 3	Excellent
CFI	0.930	>0.90	Acceptable
SRMR	0.033	<0.08	Excellent
RMSEA	0.033	<0.06	Excellent
PClose	1.000	>0.05	Excellent
p-value (ML)	0.000	>0.05	
p-value (Bollen-Stine)	0.206	>0.05	

Table 6.
Factor loadings of the observable variables of second order latent dimensions

First order factor	Standardized factor loadings	Standard error	Critical ratio (*T*-value)	R^2
G01	0.936	0.008	11.578	0.876
G02	0.932	0.008	15.167	0.868
G03	0.967	0.008	15.85	0.935
G04	0.947	0.009	14.878	0.897
G05	0.952	0.008	14.408	0.906
G06	0.947	0.008	16.323	0.898
G07	0.917	0.008	14.061	0.841
G08	0.926	0.008	13.704	0.857
G09	0.928	0.008	12.318	0.861
G10	0.890	0.008	11.994	0.791
G11	0.887	0.008	13.278	0.787

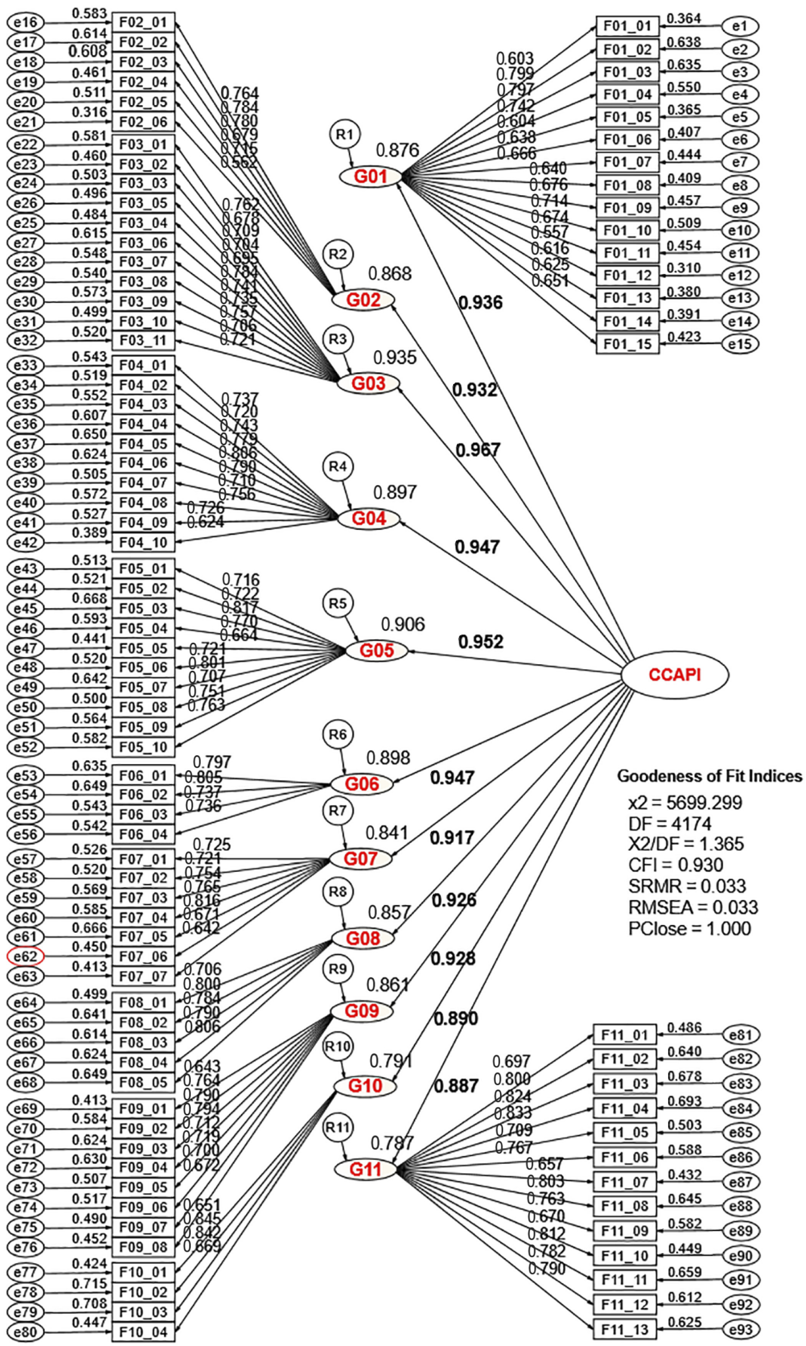

Figure 5.
Second order factor structural model for CAPM–standardized estimates

7.6 Overall internal and external validity

In quantitative research, the most common threats that are affecting the internal and external validity of the data collection and analysis are mortality, location, instrumentation, and instrument decay (Zahoor *et al.*, 2017). Precautions to minimize internal validity threats and potential biases include random sampling, a collection of data from different sectors, different organizations, different levels of experiences, professionals with different cultures. According to Cooper and Schindler (2014), internal validity can be justified by content validity and construct validity.

The review of literature establishes that poor contract administrations have been caused by improper practices of the CCA activities, and on the contrary, adequate performance is attended by the proper implementation. Therefore, a strong justification of the hypothesized causality would exist. As demonstrated, the measurement model achieved the requirement of construct validity. The instrumentation threat was minimized through a well-designed questionnaire based on a comprehensive literature review. Also, before releasing the study questionnaire, four structured interviews were conducted with experienced construction experts in construction management to enhance the questionnaire quality, ensure content validity, and minimize instrument decay threats. The location-related threats were minimized by random sampling and by spreading the survey over many professionals. Since the researcher selected large representative samples, the study would be expected to be free from method bias, and the findings would not be influenced by the actions of the researcher (Cooper and Schindler, 2014). Finally, the data was examined and treated for outliers and nonserious responses to reduce data variability and biases. The indicators were selected from several worldwide studies and not limited to a certain form of contract or region. For these reasons, the researcher argues that several actions were taken to enhance the internal and external validity of the research findings.

8. Discussion of results

In this study, an operational and multidimensional model for CCA performance is proposed, and the contract administration constructs and indicators are ranked by SFL of SEM analysis. It is worth to mention that there are only a few studies that rate or rank the CCA indicators performance. Where such studies are available, the authors cite them in the appropriate sections, and consistency with previous studies is mentioned. Where such a ranking is not available, the importance of the relevant factors and indicators are justified.

At the level of constructs, the results demonstrate that the G03-communication and relationship construct is revealed as one of the most important CCA factors (SFL = 0.967) among all other constructs. Previous studies reveal the importance of communication and relationship construct management (Joyce, 2014; Oluka and Basheka, 2014; Solis, 2016). Barakat *et al.* (2018) highlight that communication issues is one of the challenges facing the contract administration practices and argue that the contracting parties should use effective communication to successfully deliver projects on time and within budget. Effective communication supported by a feedback protocol is vital to addressing issues and better understanding among contracting parties. The G05-performance monitoring and reporting group are regarded as the second most important construct (SFL = 0.952) among all other constructs (Bartsiotas, 2014; Joyce, 2014). It is considered as a structured vehicle to ensure meeting the procurement objectives and keep all parties informed about the project status (Treasury, 2017). In addition, the literature reveals a lack of monitoring of contract-related activities, and unclear contract performance measures are regarded as main issues facing the CCA practices (Surajbali, 2016). The third important construct is G06-documents and records (SFL = 0.947). The parties' obligations are documented through a formal documentation and recording system (Appiah Kubi, 2015; Bartsiotas, 2014). Therefore, documentation and records are important for substantiating facts and supporting any event of contract execution (Treasury, 2017), complying with contract provisions and associated regulations, fulfilling obligations, and securing rights.

At the measurement model level, the results demonstrate that the F10_02-assign contractual risk responsibility within the contract risk management group is revealed as the most important CCA indicators (SFL = 0.845) to avoid unclear risk allocation (Yap, 2013). The second significant indicator is the F10_03-support employer for design risks within the contract risk management group (SFL = 0.842). The importance of this indicator is related to its negative impact on project time and cost in which rework due to design errors has been extensively reported due to errors/ omissions in drawings, specifications, or bill of quantities (Alzara *et al.*, 2016). The third important CCA indicator is the F11_04-timely review of closeout documentation within the contract closeout management group (SFL = 0.833) (Bartsiotas, 2014). The fourth indicator is F11_03-verify physical works completed within the contract closeout management group (SFL = 0.824) to avoid any slow response toward final inspection on completion (Alzara *et al.*, 2016; Iyer and Jha, 2005). The fifth indicator is F05_03-regular progress reports of the performance monitoring and reporting group (SFL = 0.817) (Solis, 2016; Treasury, 2017). The sixth indicator is F07_05-timely assessment of payments compensation within the financial management group (SFL = 0.816) to avoid delayed payments (Alzara *et al.*, 2016; Yap, 2013) and lengthy payment procedures (Okere, 2012). This finding is consistent with previous studies, which state that contractors are suffering from improper payment procedures (Abotaleb and El-adaway 2017; Okere, 2012; Surajbali, 2016), and delayed payments (Ahmed, 2015; Alzara *et al.*, 2016; Joyce, 2014; Memon and Rahman, 2013; Okere, 2012), and therefore, projects are delayed. The seventh important indicator is F11_11-timely processing of the final account within closeout management group (SFL = 0.812) (Abotaleb and El-adaway 2017) to release the contractor's retentions. The eighth indicator is F04_05-auditing contractor's health, safety, and security (HSS) of the quality and acceptance group (SFL = 0.806) to avoid consequences of poor safety management on site (Yap, 2013). The ninth indicator is F08_05-process change orders of the changes and changes control group (SFL = 0.806) where poor change management is frequently reported (Alzara *et al.*, 2016; Park and Kim, 2018) and should be managed through a proper change control management within the contract administration system (Islam *et al.*, 2019). The tenth important indicator is F06_02-use information technology of the document and record group (SFL = 0.805). Effective use of information technology in contract administration will reduce the waste of time due to transfer and paper works in addition to real-time tracking. This result is not surprising and is consistent with the finding of previous study (Joyce, 2014).

In addition to the 10 top factors, the study revealed the importance of reviewing the contractor's quality plan (SFL = 0.799) to avoid the threats of poor quality (Alzara *et al.*, 2016; Yap, 2013), timely assessment of additional payment claims (SFL = 0.794) (Treasury, 2017), early assignment of the team (SFL = 0.784) (Iyer and Jha, 2005) and regular meetings (SFL 0.784) (Alzara *et al.*, 2016; Iyer and Jha, 2005).

In spite of the importance order of the indicators and constructs, all the factors identified within the study significantly contribute to the overall performance of the contract administration process. Negligence of any item may cause misconduct of obligatory work, and therefore, no single item can be ignored or excluded.

In practice, The CAPM can be utilized as a guideline to establish a CCA management system or as an audit checklist for service compliance. Also, CAPM can be utilized as a tool for performance measurement, benchmark the service level of indicators, and evaluate the performance level of CCA team carrying out specific activities (indicators) by rating the operational performance of the indicators on scale 1 to 100. To abstract the performance level of the first and second-order constructs, the authors would recommend the relative weight approach implemented by (Gunduz *et al.*, 2017). As Such, CAPM may offer a reliable tool that helps to raise operational performance, reduce contractual problems, improve control of the project and track CCA staff performance at the successive stages of the construction phase through enhanced compliance, proper planning, awareness, effective monitoring and control of CCA activities. For specific projects where one of the project constraints may have a priority, the related indicators can be inflated by a weighting factor to present its significance over the other indicators. For specific projects where the scope of certain indicators is not applicable, the participation of these indicators can be distributed over the other indicators within the same construct. Similarly, if one or more of the constructs are not falling within the CCA scope, the construct contribution can be distributed over the other constructs.

9. Conclusions

The study establishes a multidimensional operational model to measure the CCA performance on construction projects, which contains 11 constructs and 93 indicators. The 93 indicators cover obligations of CCA function under the general conditions of the contract, the CCA team responsibilities under the professional service agreement, the best practices, success factors, and strategies to avoid consequences of poor contract administration. The importance of the indicators and underlying constructs are rated by the industry professionals through an online questionnaire, and the data is collected from 336 respondents and is then analyzed by fuzzy structural equation modeling using AMOS V24. The confirmatory factor analysis and the structured model attain the goodness of fit, individual item reliability, unidimensionality, convergence validity, and discriminate validity tests. The study shows that the communication and relationship (SFL = 0.967), performance monitoring and reporting (SFL = 0.952), and the document and record (SFL = 0.947) are the most significant constructs reflecting the CCA performance. The study recommends that management of construction projects need to focus on key indicators, such as assignment of contractual risk responsibility (SFL = 0.845), providing support to the employer for design risks (SFL = 0.842), reviewing the closeout documentation (SFL = 0.833), verification of the physical works on completion (SFL = 0.824), reporting of progress of works (SFL = 0.817), assessing payments applications (SFL = 0.816), processing of final accounts (SFL = 0.812), auditing contractor's health, safety and security (SFL = 0.806), processing of change orders (SFL = 0.806), and the use of information technology(SFL = 0.805). The proposed CAPM aims to support the contract administration team with a quantifiable multidimensional measurement tool to plan, monitor, and control the CCA performance. Furthermore, the CCA firm, the employer, and the contractor involved in multiple projects will be able to compare and benchmark the CCA performance of different projects.

Some limitations have been identified in this study. First, most of the identified indicators are extracted from the design-bid-build contracts (conventional forms of contract). Second, the model needs to be modified for non-standard forms of contracts or where additional indicators are included within the scope of the CCA team. Future studies may focus on different contract types, such as design-build and management contracts. Also, future works may use other alternative analysis techniques, such as Analytical Hierarchy Process (AHP), Fuzzy Neural Networks (FNN), and compilation of SEM with AHP.

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