Evaluating the Corruption Susceptibility Index of Infrastructure Procurement and Management in the Developed Context: The Case of Hong Kong

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Abstract

This study evaluates the susceptibility patterns of the procurement process of infrastructure projects to corruption in Hong Kong. An expert-survey is conducted with infrastructure-related professionals from Hong Kong (HK) using non-probabilistic sampling approaches. A total of 38 responses comprising of both close-ended and open-ended responses were retrieved and analyzed. This study employed a soft computing technique coupled with other descriptive tools to evaluate the susceptibility patterns. Whereas the contract stage of the process was revealed to be the highest-ranked susceptible stage of the procurement process, the model indicates that the procurement process in HK is relatively less prone to corrupt practices. Given that there are notable studies on the subject matter, this study arguably remains one of the first to examine the susceptibility patterns of the stages within the infrastructure procurement process to corruption in a specific context of the developed region. It contributes to the existing knowledge of corruption in infrastructure project procurement by revealing the respective stages of the procurement process that require more in-depth investigations and more stringent efforts in not only extirpating the vulnerabilities but also developing measures that will safeguard the procurement process and related activities from corruption. The approach adopted in this study can guide the assessment of similar corruption-related constructs in other contexts or regions.

`**Keywords**: Corruption; Infrastructure Projects; Susceptibility Index (SI); Fuzzy Synthetic Evaluation (FSE); Project Management; Hong Kong.

Introduction

According to Kim (2016), public procurement (which connotes the purchases of goods, work, and services) is estimated to account for more than 30% of gross domestic product (GDP) in the developing countries and within the range of 10% to 15% in the developed regions. Moreover, it is estimated to account for 12% of GDP in the Organization for Economic Co-operation and Development (OECD) countries (OECD 2018). As a result, the misappropriation of funds allocated for infrastructure can pose a significant risk to the economy (Chan and Owusu, 2017). This case is not uncommon in the developing world as excerpts of corrupt acts have been identified in almost every developing country (Hunga, 2003) and from further annual publication on countries' standings regarding the proliferation of corruption (Transparency International, 2018). However, in developed economies such as the UK, USA, Australia, Hong Kong, and Singapore, some effective measures have been stipulated to check the widespread and menace of corruption (Owusu et al., 2017). The measures include stringent supervision, rigorous auditing, the adoption of e-procurement, education, contract monitoring, and reactive measures such as harsh punishment and other disciplinary actions among others (Neupane et al., 2014; Zou, 2006; Tabish and Jha, 2012; Le et al. 2014; de Jong et al., 2009).

The case of Hong Kong can be employed as an excellent example of how developed regions that were once regarded as corrupt have been able to extirpate the widespread of corrupt practices through the steady development, enforcement, and application of the stipulated anti-corruption frameworks and policies. Prior to the formation of the Independent Commission Against Corruption (ICAC), Hong Kong was revealed to be one of the most corrupt cities in the world (Cheung, 2008). However, according to Yeung (2002), the case has reversed with time, and Hong Kong is now regarded as one of the clean regions in the world regarding corruption. Studies show that in evaluating the efficacy of efforts implemented to tackle corruption, there is an apparent agreement among scholars that Hong Kong's ICAC stands to effectively transform its society in the direction of an environment that is less prone to corruption. Also, the institution records a very minimal level of corruption as compared to its correlative agencies such as the ICAC of Korea (Quah, 2013; Bhargava and Bologaita, 2004; Choi, 2009). However, despite the effective and transformational efforts offered by the ICAC, traces of corruption still linger within the public infrastructure sector. A typical example was revealed in a fraudulent incident (costing over HK$58 million) during the construction of the World's longest sea bridge that connects Hong Kong, Zhuhai, and Macau (Lin and Han 2019; Wong 2019). Moreover, per the literature reviews conducted, it was identified that limited efforts had been expended on examining how vulnerable individual activities (with their respective stages) of the procurement process are even in the developed regions like Hong Kong. Against these backdrops, this study is aimed at assessing one of the key challenges posed to the public sector, that is, corruption in the procurement process of infrastructure works. That is, to examine the susceptibility levels of the activities and the stages within the procurement process. This study's results are intended to offer relevant information to project participants regarding the procurement stages with their respective activities that are prone to the incidence of corruption. Thus, helping to enhance transparency throughout the process. As a relevant input to scholarly works, this study contributes to the widened understanding of the dynamics of corruption throughout the procurement process.

The study is structured into six sections. The first or introductory section (i.e., this section) presented a brief background of the subject matter, the identified gap, the study's aim, and the objective stipulated to realize the study's aim. Section 2 presents the literature review on the subject matter (i.e., Corruption Vulnerabilities (Irregularities) within the procurement process. Sections 3 explicates the research design of the study, while the fourth section presents the analysis and results of the data gathered, including the Fuzzy Synthetic Evaluation (FSE) computations. Section 5 presents the discussion of the data and associated implications and limitations. Finally, section 6 concludes the study.

Corruption Vulnerabilities (Irregularities) within the procurement process

None of the stages of the procurement process, according to Zou (2006), is resistant to the incidence of corruption. As the name implies, corruption vulnerabilities refer to systematic loopholes or 'red-flags' and are not necessarily causes of corruption, but they can trigger the incidence of corrupt practices (Le et al., 2014b). They can be referred to as indirect actions of project parties that may lead to corruption in the long run. In order words, parties involved may not have the mindset to indulge in corruption. However, due to systematic loopholes arising from a project, project parties may be lured to involve themselves in practices that may threaten the entire process of IP and potentially lead to corruption (Le et al., 2014; Tabish and Jha 2011). For instance, 'work not executed as per the original specified design' identified in the study of Le et al. (2014) as a risk indicator may not necessarily be a causal factor of corruption. However, they can serve as 'red flags' that have the potency to lead to corrupt behaviors if proper investigations are not carried out to determine the rationale behind the indicators.

On the other hand, there are other identified risk factors that are explicitly geared towards corruption. For instance, according to the ICAC (2018), some of the risk factors that can render the procurement process susceptible to the incidence of corruption include blurred policy and the inducement of public parties or project participants to exploit the procurement process for their private gain. Other factors include inconsistencies in practices coupled with the prospect for parties' manipulations, inadequate division of labor or allocation of duties which offers enough room for project parties to cover up their corrupt acts, and the lack of supervision and administration oversight, which complicates the detection of the loopholes or irregularities. Moreover, with respect to the specificity of the individual activities and stages captured under the procurement process, a number of critical risk factors were identified. They include the absence of scrupulous requirements, unclear specifications, and the practice of using brand names at the stage of preparing documentation related to tender quotations; demonstrating favoritism and unfairness by inviting favorite contractors or suppliers to bid, coupled with the mishandling of contractor/suppliers' list during the period of sourcing for suitable contractors or suppliers. Other risks include leaking any vital information related to tender or quotations prior to the receipt of tenders or quotations from suitable bidders and skewed assessment (being biased to favor) towards a particular bidder. Lastly, the lack of checks and balances at the stage where there is the need for checking and ensuring the proof of delivery (which may lead to the delivery of inferior products) and the challenges emanating from the limitations regarding performance monitoring system are also considered to be some of the leading risks (ICAC 2018; Stansbury 2009b; Owusu et al. 2017). These loopholes may constitute a fraction of the numerous factors that render the procurement process vulnerable to the incidences of corrupt practices.

Unlike the other topical constructs of corruption (i.e., forms, causes, anti-corruption measures (ACMs)) that are more general, corruption risk indicators are more context-specific (Tabish and Jha

201; Le et al. 2014). One of the early works to explore this area was conducted on public procurement operations in India (Tabish and Jha 2011). The study was conducted to analyze the irregularities in Indian's public procurement. The authors identified 61 different irregularities that could be regarded as 'red-flags' to corrupt practices in the Indian procurement works. These variables were further categorized into five main components, namely: transparency irregularities, professional standards irregularities, fairness irregularities, contract monitoring, and regulation irregularities, and lastly, procedural irregularities. However, these variables cannot be generalized since almost all of them identified in a report compiled by the Chief Technical Examiner of India. In 2014, Le et al. (2014b) conducted a similar study to identify the irregularities in the Chinese construction public sector, and they identified 24 irregularities peculiar to the Chinese public construction sector. As highlighted earlier, these variables are not necessarily corrupt practices but rather indicate the potential risks or the possibilities that corruption could occur. The variables can also be used to measure how prone, vulnerable, or weak an organization or a state institution is to the incidence of corruption with associated liabilities. Thus, the assessment of the respective constructs of corruption is required to ascertain how the criticalities and the impacts of the constructs can be extirpated.

These irregularities, together with other causal factors of corruption, can transpire across any stage of the procurement process or in any of the activities captured under the different stages (Tabish and Jha 2011; OECD 2016; Bowen et al. 2012). Given the suppositions underlying the disparities of the criticalities associated with the procurement irregularities, this study intends to examine the activities and stages presented in Table 1 to ascertain their individual susceptibility levels. The overarching aim is to help determine which of the activities or stages require greater attention in terms of dealing with the susceptibility of the stages as well as the criticalities of the irregularities. The succeeding section presents the research methods used in this study.

[Insert Table 1 Here]

While this study remains one of the first to explore the vulnerability indexes of the respective activities and stages of the procurement process, it must be emphasized that a number of related studies have explored some of the critical constructs of corruption in construction and offer infrastructure-related works. Some of these important works include the behavioral factors that influence or instigate corruption in the Australian industry and the corruption constructs in other developed regions such as Italy (Locatelli et al. 2017). The exploration of other relevant constructs such as the forms and causal factors of corruption as well as corruption irregularities in different contexts such as South Africa (Bowen et al. 2012); India (Sohail and Cavil 2018), and China (Zhang et al. 2017) are among some of the relevant studies conducted within the scholarship domain. However, despite the exploration of all these relevant and constructs of corruption, the estimation of how the processes involved in the procurement and constriction remain vulnerable to corruption, particularly in the developed region, represents one of the significant gaps that this study intends to bridge.

Lastly, a recently published study by Owusu et al. (2020) investigated the effectiveness of the anti-corruption measures (ACM), and frameworks stipulated to extirpate the prevalence and impacts of corruption in infrastructure project procurement and management in Hong Kong. Among over twenty-six notable measures and frameworks, the authors identified that the overall ACM strategy in HK is effective. This is mostly justified by the reports of International Anti-corruption advocacy groups such as Transparency International, United Nations Office on Drugs and Crime, and the World Economic Forum, among others. One supposition that can be postulated from the previous study of Owusu et al. (2020) is that the effectiveness of ACMs contributes to low criticalities of the negative constructs of corruption, such as the causal factors of corruption and procurement irregularities. Moreover, it can attenuate the likelihood of the procurement process and related activities of infrastructure-related projects to be vulnerable to corruption. Thus, a low vulnerability index can further strengthen or justify the supposition regarding the effectiveness of the stipulated ACMs and vice versa. Put simply, a procurement process with low vulnerability levels to corruption can be attributed to effective ACMs and vice versa. Following the assessment of the ACMs' effectiveness by Owusu et al. (2020), this study examines how vulnerable the procurement process of infrastructure-related projects is to corrupt acts. Given the suppositions made, the effective ACMs identified in the mentioned study is supposed to result in relatively lower vulnerability levels regarding the procurement process and related activities.

Methodology

Analogous to other constructs explored under this (research project) study, the credible views of the experts involved in either all or major parts (activities) of the procurement process were solicited to measure the levels of vulnerabilities of the stages of the procurement process with their respective activities. To begin, a questionnaire aimed at soliciting both qualitative and quantitative views of the experts was developed. Even though other data solicitation techniques, such as participant observation documentary records, and case studies, among others, were considered apropos for gathering the data needed. Among the numerous advantages for finally adopting the use of questionnaires to solicit for both qualitative and quantitative, five are stipulated below:

1) The study aimed to adopt a quantitative approach for assessing the vulnerability indices of the activities and the stages of the procurement process even though an equal emphasis was placed on the qualitative views expressed by the respondents (Shan et al., 2015). 2) Considering a sensitive topic of this nature, the assurance of data confidentiality, as well as the anonymity of the respondents, formed a crucial part of the study. The use of questionnaires is identified to be paramount among other data solicitation techniques to address these two issues (Ameyaw et al., 2017). 3) The format of the questions to be asked were technically structured and pilot tested. The experts involved in the pilot study had no objections to the use of questionnaires to solicit expert data regarding this construct. 4) This technique has been employed by past studies to explore topics or issues of this nature due to its advantage of providing valid and reliable information within a limited period and at a relatively cheaper rate (Owusu and Chan 2018). 5) Lastly, it ensures an applicable number of questions to be explored as well as a relatively higher or greater number of people (respondents) to be surveyed (Le et al., 2014b).

Moreover, since the study was structured to employ a quantitative model for evaluating the vulnerability indices for the activities and their respective stages, it was needful to establish the activities captured within the procurement process objectively. A list of twenty-one unique and yet interrelated activities was identified and structured under four primary constructs (or stages) within the procurement process, namely: 1) the pre-contract stage, 2) the contract stage, 3) the contract administration stage, and lastly, 4) post-contract phase. The experts were asked to evaluate the activities using 5-point grading scale systems, which commence from 1= very low, 2= low, 3=neutral, 4=high, and 5=very high.

Sampling and Survey Participants

Non-probabilistic sampling approaches, namely purposive and snowball approaches, were employed to reach out to the experts needed for the survey. These two approaches were adopted due to their respective advantages. However, the ultimate advantage was attributed to the need of reaching to experts who possessed the relevant knowledge and experience to respond to the survey (Crossman 2018). These two approaches were, however, employed at different time stands. The purposive approach was the first to be used to reach the experts. Given the possibility that the experts may know or work with other colleagues who possess similar knowledge, skills, and experience, the experts who accepted the invitation were requested to help disseminate the questionnaire to other experts within their domain of work. As established, the survey solicited the views of experts involved in the supply chain of the procurement process irrespective of the professional backgrounds as well as other construction-related activities involving the procurement of goods, works, and services. As an expert survey, one key criterion that the selection of the respondents was to scout and identify professionals involved in any of the procurement stages described above. Moreover, since the scope under investigation was Hong Kong, the experts involved are from Hong Kong and are involved in the supply chain of procurement works undertaken in Hong Kong and also understand the dynamics of corrupt acts in the procurement process and other construction-related works. The bio-data summary of the experts involved is presented in Table 2. In the end, a total of 38 responses were regarded as apropos for the needed analysis to be conducted. In as much as the number of responses may be regarded as relatively small, they were considered analyzable following at least five justifications listed below;

1) The sample size exceeds the threshold regarding the central limit of thirty responses, which are often needed to make justifiable conclusions (Ling et al., 2009; Ott and Longnecker, 2001). Even though the excess may be regarded as relatively smaller (i.e., eight), the justification that significant deductions can be drawn from the responses makes it apropos to be analyzed. 2) The number of responses retrieved is consistent with other corruption-related studies in the field of construction management. Examples include Ameyaw et al. (2017), who explored corrupt practices in the Ghanaian construction industry using a sample size of 35. Brown and Loosemore (2015) also explored the behavioral instigators of corrupt action in the construction industry of Australia with 23 sample size,

Vee and Skitmore (2003), with 31 responses while Tabish and Jha's (2011) findings were based on six participants. All these are corruption-related studies that explored diverse constructs of corruption in the context of construction and engineering management. One of the common drawbacks of studies related to corruption is the unwillingness of the potential respondents to be involved. 3) The research project was time-bound, and the time estimated for the data collection was long overdue, with an unusual set of numerous reminders that spanned for more than eight months. 4) Since the purposive sampling technique was employed, the selection of the experts was purely based on the possession of both practical (experiential) and theoretical knowledge, as well as their willingness to be involved. The number obtained was the suitable representation of the requirement after some respondents explicitly shared their concerns of not possessing thorough knowledge about the procurement process, and some were as well unwilling to get involved (Tongco 2007; Owusu and Chan 2019). 5) Lastly, obtaining a relatively larger sample size for topics regarding corruption in construction and engineering management related studies is somewhat difficult (Ameyaw et al., 2017; Brown and Loosemore, 2015).

Data Analysis and Results

In analyzing the data gathered as well as developing the vulnerability index (VI) model, it is vital to select the choicest tools to give a more reliable and accurate result. As such, two pre-tests were conducted to determine the study's data reliability and normality. Secondly, the descriptive, including mean indices and frequencies for the activities of the procurement process, were determined since they formed the foundational indices for the application of the fuzzy synthetic evaluation (FSE) technique. Thirdly, the FSE technique was adopted to assess the vulnerability indices for both the stages constructs involved in the procurement process as well as the overall vulnerability index. Further details regarding these tools, including the justification of their adoption, are discussed below.

Pre-Tests

Prior to the commencement of detailed analysis, different scholars had stipulated the need to determine the reliability of the data (Ameyaw et al. 2017; Le et al. 2014a). This is regarded as one of the basic and most important pre-tests which determine whether further analysis of the data can be conducted. The data reliability was determined by conducting the Cronbach Alpha's (CA) test. Per the stipulation of **Nunnally (1978),** the threshold for establishing a statistically reliable dataset should not be less than 0.7. With the given range of 0 to 1 as the extreme variants or estimates, the greater the calculated reliability nears zero, the lesser its reliability and vice versa. Zero indicates no reliability, whereas one indicates full reliability. The actual estimated CA for this study was 0.958, which reflects an extremely high level of reliability. Thus, showing that the data is reliable and adequate for further processing.

[Insert Table 2 Here]

Determining the Mean Values

As previously stated, prior to the estimation of the constructs (stages) indices, there was the need to evaluate the indices of the individual activities in the procurement process. The mean evaluation technique was adopted to estimate the activities of the procurement process using the SPSS software (v. 23). The MEA was employed to evaluate the vulnerability levels of the procurement activities. Referring to the indicators of scales employed to evaluate the variables (i.e., activities) which are 1= very low; 2 = low; 3 =Neutral; 4 = high; 5= very high (for the procurement activities), an analogous reference is made to the calculated or generated mean values (i.e., the closer an index of a variable to 1, the lesser its vulnerability or criticality and vice versa). The individual mean values for the activities are presented in table 3 and figure 1, respectively.

The Fuzzy Synthetic Concept

The FSE is a modeling technique that stems from the fuzzy set theory and is used to measure multiattribute and multi-evaluation of measurement items (Hu et al., 2016; Ameyaw and Chan, 2015a). Fuzzy set, as the name implies, refers to a set that has a different or changing degree of membership, which varies in a defined interval of 0 and 1. This means that if an element has a membership grade that falls on the level of zero, it cannot be considered as a member of the set. On the other hand, any element with grade membership in the degree of one possesses an absolute relationship to the set (Hadipriono, 1988). As a modern mathematical tool, it is employed to handle or examine complex and ill-defined fuzzy situations due to the condition that vague and incomplete data represent problems of the real world (Osei-Kyei and Chan, 2017). This method was firstly introduced by Zadeh (1965) to address the issues of uncertainties and subjectivities. According to Sign and Toh (2005), the values of the membership function characterizes the level of belongingness of an individual element to a set. In other words, an element may belong to a fuzzy set either by a greater or lesser degree represented by either a larger or smaller membership value. This tool has been employed to solve many practical problems since it was first introduced (Wei et al. 2010). Fuzzy concepts offer a suitable technique for analyzing intricate systems when the indeterminacy pattern is inferable to inherent vagueness and variability. Moreover, it is employed to model the processes involved in decision-making (Zadeh, 1994; Boussabaine, 2014).

Previous studies assert that FSE is deemed to be one of the most suitable approaches to multi-criteria synthetic evaluation, as well as the assessment of multi-criteria decision-making and also one of the most significant research content in the fuzzy environment (Xu et al., 2010; Sadiq and Rodriguez, 2004; Wei et al., 2010). For instance, policy and decision-makers in project management such as stakeholders, regulators, engineers, and project managers usually view the level of project risk regarding linguistics determinants as very high, high, moderate, low, very low, etc. (Sadiq and Rodriguez, 2004; Tah and Carr, 2000). The FSE technique is construed to be hierarchical as it can be employed to compute an overall index from the base level of the input variables (i.e., the list of the activities). Simply put, it accumulates and synthesizes the input variables to estimate an overall index of a given dataset. The preferability of the FSE technique over other arithmetic evaluation tools is attributed to the ability to process vague, uncertain, and linguistic variables that can be used for approximate reasoning, such that it can be manipulated to eliminate or objectify the uncertainties involved with the decision process. The FSE technique is employed in this study to evaluate the vulnerability indices of the stages or constructs of the procurement stages and their respective activities within the procurement process. The processes involved in the FSE approach is given below:

1. Establishing a set of factors or basic criteria, $U = \{u_1, u_2, u_3 \ldots, u_m\}$ *where* u_i = *(i=1,2,3,…..m)* represents the i^{th} factor estimation;

2. Create a set of grade substitutes which are detailed in linguistic terms for the variables *V= {*$v_1, v_2,$ v_3 *……,* v_m*} where* v_j *= (j=1,2,3,…..m)* represents the evaluation grade *j*. In simple terms, the grade substitute represents the employed measurement scale.

3. Create a set of weightings by evaluating the weight vectors of the evaluation variables as *W= {*w_1*,* w_2*,* w_3 *……*w_m*} where* w_j *= (j=1,2,3,…..m)* signifies an evaluation factor I weighting and ($0 \leq w_j \leq 1$). The weightings for the respective stages and activities are computed using the formula below:

$$w_i = \frac{M_i}{\sum_{i=1}^{5} M_i}, 0 < w_i < 1, and\ \sum_{i=1}^{5} w_i = 1 \qquad \text{eqn.1}$$

Where w_i connotes the individual weightings of the procurement activities within the constructs *i*; M_i, represents the procurement activities' mean values.

4. Determination of a fuzzy evaluation matrix R=$(r_{ij})_{m \times n}$ where (r_{ij})expresses the degree to which an alternative $v_j$satisfy the basic criterion u_i in a fuzzy environment. The matrix of the fuzzy function R can be expressed as:

$$R=\begin{bmatrix} r_{11} & r_{12} \cdots & r_{1n} \\ r_{21} & r_{22} & r_{2n} \\ \vdots & \vdots & \vdots \\ r_{m1} & r_{m2} \cdots & r_{mn} \end{bmatrix} \qquad \text{eqn.2}$$

5. Estimate the final results of the fuzzy evaluation by taking into consideration the weightings determined in step 3 and the matrix in step 4 using the equation (3) given below:

$$\boldsymbol{D_i}=\boldsymbol{W}\ x\ \boldsymbol{R}= (d_{i1}, d_{i2}, \ldots d_{in}) \qquad \text{eqn.3}$$

Where D_i stands for the final evaluation matrix of a given procurement stage; W=weighting vector; R= fuzzy evaluation matrix and $'x'$ represents the fuzzy composition operator.

The computational values obtained for D_i will now represent the fuzzy matrix $\bar{R}$ to determine the overall vulnerability index for the procurement process.

$$\text{Therefore, } \bar{R} = \begin{bmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \\ d_{41} & d_{42} & d_{43} \end{bmatrix} \qquad \text{eqn.4}$$

The values in the set $\boldsymbol{D_i}$ $(i = 1, 2, 3, 4)$ connote the respective stages of the procurement process (i.e., 1 = PCS, 2 = CTS, 3 = CAS, 4 = PCP). Thus, with reference to equation 3, $\bar{R}$ is normalized via the weighted values $\overline{w}_{\boldsymbol{i}}$ of the individual stages of the procurement process $(w'_1, w'_2, w'_3, \ldots w'_n)$ to obtain the fuzzy matrix for estimating the overall vulnerability index $\overline{D}_{\boldsymbol{i}}$.

Mathematically, $\overline{D}_i = \overline{\mathrm{w}}\ x\ \overline{\mathrm{R}} = (w'_1, w'_2, w'_3, w'_4) x \begin{bmatrix} d_{11} & d_{12} & d_{13} \\ d_{21} & d_{22} & d_{23} \\ d_{31} & d_{32} & d_{33} \\ d_{41} & d_{42} & d_{43} \end{bmatrix} = (\mathrm{d}'_1, \mathrm{d}'_2, \mathrm{d}'_3, \mathrm{d}'_4)$ eqn.5

Where $\overline{D}_i$ $(\mathrm{i.e.}, \mathrm{d}'_1, \mathrm{d}'_2, \mathrm{d}'_3, \mathrm{d}'_4)$ represents the fuzzy evaluated matrix or the membership functions of the entire constructs of the procurement process, which is employed to estimate the overall vulnerability index by multiplying through the grading system *(j =1, 2, 3, 4, 5)* using the formula below:

$OVI = \sum_{k=1}^{5} \overline{D} \times V = (d'_1, d'_2, D'_3, D'_4,) \times (1,2,3,4,5), 1 \leq OVI \leq 5$ - eqn. 6, where OVI represents the overall vulnerability index. This stage is commonly known as defuzzification, meaning that the fuzzy members have now been converted into more comprehensible or crisp estimates, which can be used to facilitate a decision-making process or make informed judgments (Sadiq and Rodriguez 2004; Ameyaw and Chan 2015).

Data Analyses and Results

To commence, the evaluation system for analyzing the vulnerability indices for the four stages of the procurement process is established by developing the constructs representing the stages as the first level index system (Shao 2004; Ameyaw and Chan 2015a). They are therefore represented as (U_1, U_2, U_3, U_4), which is represented in the context as (U_{PCS}, U_{CA}, U_{CAS}, U_{PCP}). The activities within the respective Stages would, therefore, represent the second- level index system, which can as well be defined as $U_{PCS} = \{u_{pcs1}, u_{pcs2}, u_{pcs3}, u_{pcs4}, u_{pcs5}, u_{pcs6}\}$; $U_{CTS} = \{u_{cts1}, u_{cts2}, u_{cts3}, u_{cts4}, u_{cts5}\}$; $U_{CAS} = \{u_{cas1}, u_{cas2}, u_{cas3}, u_{cas4}\}$; $U_{PCP} = \{u_{pcp1}, u_{pcp2}, u_{pcp3}, u_{pcp4}, u_{pcp5}, u_{pcp6}\}$. The estimated index system will, therefore, form the input variables for the FSE (Xu et al. 2010). The activities are ranked following a 5- point Likert grading system as I= (1,2,3,4,5) where 1 represents very low, 2=low, 3= moderately low, 4= high, 5= very high. This is analogous to other studies (Osei-Kyei and Chan 2017).

Calculating the weightings for the input variables

The weighting of the input variables for both the constructs (stages) and the activities are computed from the normalization of the mean variables estimated from the responses from the general survey (Ameyaw et al. 2015b; Osei-Kyei and Chan 2017). Thus, it is calculated using the formula in equation (1). Using CTS_4 as an example, the weighting in estimated below:

$$W_{cts_4} = \frac{2.53}{2.32 + 2.68 + 2.92 + 2.53 + 2.34} = \frac{2.53}{12.79} = 0.198$$

The summation of all the weightings of the activities within a construct must equate one. Therefore, the computation or summation of the contract stage (CTS) construct can be calculated below:

$$\sum_{k=1}^{5} W_{cts} = 0.181 + 0.210 + 0.228 + 0.198 + 0.183 = 1.00$$

[Insert Table 3 Here]

Calculating the membership functions (MFs) of the input variables (Level 3)

The degree (between 0 and 1) of an element's or a variable (in this case, the activities) membership in a fuzzy set is called the membership function (MF) in the FSE context (Ameyaw and Chan 2017 2017; Xu et al. 2010). The designation of the various levels where the MFs are derived, therefore, remains critical (Ameyaw and Chan 2015a). The intrinsic terms used in assessing the input variables against the constructs were therefore evaluated using the 5-point Likert system as S = (1,2,3,4,5) where S_1=very low, S_2= low, S_3=neutral, S_4= high, S_5=very high. The MF of a given variable/activity within a stage is therefore captured following the formula below:

$$MF_{a_{in}} = \frac{x_{1a_{in}}}{S_1} + \frac{x_{2a_{in}}}{S_2} + \frac{x_{3a_{in}}}{S_3} + \frac{x_{4a_{in}}}{S_4} + \frac{x_{5a_{in}}}{S_5} = \frac{x_{1v_{in}}}{very\ low} + \frac{x_{2v_{in}}}{low} + \ldots + \frac{x_{3v_{in}}}{very\ high}$$ and expressed as

$$MF_{a_{in}} = (x_{1_{a_{in}}} + x_{2_{a_{in}}} + x_{3_{a_{in}}} + x_{4_{a_{in}}} + x_{5_{a_{in}}}).$$ equation (7)

Where MF designates the activity's membership function v_{in}, xyv_{in} (y=1, 2, 3, 4, 5) represents the percentage of the respondents who score an activity (y). With reference to the scores obtained from the expert survey, the membership functions of the procurement activities are computed using the direct scores or ratings ascertained from the experts. Thus, using the activity PCS4 (i.e., obtaining necessary approvals) as an example, the Likert scale values as scored by the experts were as follows; 26% for very low, 26% for low, 34% for neutral, 13% for high and 0% for very high. These estimations are therefore used to ascertain the MFs at the third level via equation 7 as follows:

$MF_{PCS_4} = \frac{0.26}{Not\,Vulnerable} + \frac{0.26}{Less\,Vulnerale} + \frac{0.34}{Neutral} + \frac{0.13}{Vulnerable} + \frac{0.00}{Extremely\,Vulnerable}$ and expressed as (0.26, 0.26, 0.34, 0.13, 0.00).

Analogous to the MFs for PCS4, the membership functions for the remaining activities are computed using survey ratings provided by the experts. The estimated membership functions for the remaining procurement activities are presented in Table 4.

Calculating the for the MFs Procurement Stages (Level 2)

Following the computations of the MFs at level three are the estimations of the MFs at level two (i.e., for the individual constructs or stages). The MFs at this level are derived following the formula in eqn.3. That is, $D = W_i x R_i$;

where W_i represents the weightings of the activities within the procurement stages. R_i connotes the fuzzy evaluation matrix. The weightings are computed following a similar approach used in equation 1, and their summation must equate one. The weightings for all the constructs are thus calculated as follows:

$$W_{CTS} = \frac{14.29}{14.29 + 12.79 + 9.63 + 13.95} = \frac{14.29}{50.66} = 0.282$$

$$W_{CAS} = \frac{12.79}{14.29 + 12.79 + 9.63 + 13.95} = \frac{12.79}{50.66} = 0.252$$

$$W_{PCP} = \frac{9.63}{14.29 + 12.79 + 9.63 + 13.95} = \frac{9.63}{50.66} = 0.190$$

$$W_{PCS} = \frac{13.95}{14.29 + 12.79 + 9.63 + 13.95} = \frac{13.95}{50.66} = 0.275$$

$$\sum_{i=1}^{4} w_i = 0.282 + 0.252 + 0.190 + 0.275 = 1$$

The estimated values are presented as $w_i = (0.282, 0.252, 0.190, 0.275)$. The fuzzy evaluation matrix is derived from the MFs of the activities within their respective constructs and is presented as follows:

$$\mathrm{R_i} = \begin{vmatrix} MF_{a_{i1}} \\ MF_{a_{i2}} \\ MF_{a_{i3}} \\ \cdots \\ MF_{a_{in}} \end{vmatrix} = \begin{vmatrix} x_{1_{a_{i1}}} & x_{2_{a_{i1}}} & x_{3_{a_{i1}}} & x_{4_{a_{i1}}} & x_{5_{a_{i1}}} \\ x_{1_{a_{i2}}} & x_{2_{a_{i2}}} & x_{3_{a_{i2}}} & x_{4_{a_{i2}}} & x_{5_{a_{i2}}} \\ x_{1_{a_{i3}}} & x_{2_{a_{i3}}} & x_{3_{a_{i3}}} & x_{4_{a_{i3}}} & x_{5_{a_{i3}}} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{1_{a_{in}}} & x_{2_{a_{in}}} & x_{3_{a_{in}}} & x_{4_{a_{in}}} & x_{4_{a_{in}}} \end{vmatrix} \qquad \text{equation (8)}$$

The Pre-contract stage (PSC) can be presented as:

$$R_{a_{pcs}} = \begin{vmatrix} MF_{a_{pcs1}} \\ MF_{a_{psc2}} \\ MF_{a_{pcs3}} \\ MF_{a_{pcs4}} \\ MF_{a_{pcs5}} \\ MF_{a_{pcs6}} \end{vmatrix} = \begin{vmatrix} 0.16 & 0.39 & 0.34 & 0.08 & 0.03 \\ 0.21 & 0.42 & 0.26 & 0.05 & 0.05 \\ 0.13 & 0.47 & 0.24 & 0.13 & 0.03 \\ 0.26 & 0.26 & 0.34 & 0.13 & 0.00 \\ 0.24 & 0.26 & 0.32 & 0.18 & 0.00 \\ 0.32 & 0.32 & 0.13 & 0.21 & 0.03 \end{vmatrix}$$

Therefore, using a similar formula $D = W_i x R_i;$ in equation (3), the presentation and computation of the PCS are listed below:

$$D_{a_{cts}} = W_{pcs} x R_{pcs} = (w_{pcs1}, w_{pcs2}, w_{pcs3}, w_{pcs4}, w_{pcs5}, w_{pcs6}) \times \begin{vmatrix} MF_{a_{pcs1}} \\ MF_{a_{psc2}} \\ MF_{a_{pcs3}} \\ MF_{a_{pcs4}} \\ MF_{a_{pcs5}} \\ MF_{a_{pcs6}} \end{vmatrix} \approx D_{a_{pcs}} =$$

$$(0.169, 0.162, 0.171, 0.164, 0.171, 0.162) \times \begin{vmatrix} 0.16 & 0.39 & 0.34 & 0.08 & 0.03 \\ 0.21 & 0.42 & 0.26 & 0.05 & 0.05 \\ 0.13 & 0.47 & 0.24 & 0.13 & 0.03 \\ 0.26 & 0.26 & 0.34 & 0.13 & 0.00 \\ 0.24 & 0.26 & 0.32 & 0.18 & 0.00 \\ 0.32 & 0.32 & 0.13 & 0.21 & 0.03 \end{vmatrix}$$

$D_{a_{cts}} = (0.22, 0.36, 0.27, 0.13, 0.02)$.

The results $D_{a_{cts}} = (0.22, 0.36, 0.27, 0.13, 0.02)$ represents the membership function values for the construct stage which is made up of five activities. Going through the same approach for computing $D_{a_{cts}}$, the remaining three stages (i.e., pre-contract stage, contract administration stage, and post construct stage are computed to determine the MFs for each of the stages. The results obtained for each of the stages are further processed to arrive at the membership function at level 1. The respective MFs for all the stages are presented in table 4.

[Insert Table 4 Here]

Computing Vulnerability Indices for the Procurement Stages

The derivation of the MFs for the individual stages of the procurement process enables the actual vulnerability indices (VI) for the constructs to be estimated. The formula for estimating the VI is as:

$VL_i = \sum_{k=1}^{5} D \times V^t = (d_1, d_2, d_3, d_4, \dots d_n) \times (1,2,3,4,5)$

The overall vulnerability level for the individual IP stages or construct is calculated using the example of the CTS construct below:

$VL_{pcp} = [(0.22 \times 1) + (0.36 \times 2) + (0.27 \times 3) + (0.13 \times 4) + (0.02 \times 5)] = 2.38$.

Similarly, $VL_{cts} = [(0.22 \times 1) + (0.30 \times 2) + (0.26 \times 3) + (0.15 \times 4) + (0.08 \times 5)] = 2.58$;

$VL_{cas} = [(0.18 \times 1) + (0.40 \times 2) + (0.27 \times 3) + (0.13 \times 4) + (0.03 \times 5)] = 2.41$;

$VL_{pcp} = [(0.20 \times 1) + (0.41 \times 2) + (0.25 \times 3) + (0.11 \times 4) + (0.03 \times 5)] = 2.34$.

From the computations of all the vulnerability levels or indexes (VLn) (i.e., VLpcs, VLcts, VLcas, VLpcp), it can be concluded that none of the individual stages was revealed to be vulnerable. On the contrary, other than the contract stage that was realized to be neutral in terms of the stages' vulnerability levels, the remaining stages were all identified to be less vulnerable. The VL of each of the stages is graphically presented in Figure 1.

[Insert Figure 1 Here]

Computing the Overall Vulnerability Indices (OVI) for the Procurement Process

The estimated Vis in the preceding section formed the basis for the computation of the OVI. However, employing a similar formula used in equation (3) (i.e., $W_i x R_i$),

$$\bar{R} = \begin{vmatrix} D_1 \\ D_2 \\ D_3 \\ D_4 \end{vmatrix} = \begin{vmatrix} d_{11} & d_{12} & d_{13} & d_{14} & d_{15} \\ d_{21} & d_{22} & d_{23} & d_{24} & d_{25} \\ d_{31} & d_{32} & d_{33} & d_{34} & d_{35} \\ d_{41} & d_{42} & d_{43} & d_{44} & d_{45} \end{vmatrix}$$

In this case, the $\bar{R}$ connotes the fuzzy matrix for calculating the OVI, D_i $(i = u_1, u_2, u_3, u_4)$ represents the evaluated matrix. The matrix is therefore presented as:

$$\bar{R} = \begin{vmatrix} D_{psc} \\ D_{cts} \\ D_{cas} \\ D_{pcp} \end{vmatrix} = \begin{vmatrix} 0.22 & 0.36 & 0.27 & 0.13 & 0.02 \\ 0.22 & 0.30 & 0.26 & 0.15 & 0.08 \\ 0.18 & 0.40 & 0.27 & 0.13 & 0.03 \\ 0.20 & 0.41 & 0.25 & 0.11 & 0.03 \end{vmatrix}$$

The evaluated matrix is normalized through the estimated weightings of the stages $(w_{pcs}, w_{cts}, w_{cas}, w_{pcp})$ as follows:

$$\bar{D} = \bar{w} x \bar{R} = (w_1, w_2, w_3, \ldots w_i) x \begin{vmatrix} d_{11} & d_{12} & d_{13} & d_{14} & d_{15} \\ d_{21} & d_{22} & d_{23} & d_{24} & d_{25} \\ d_{31} & d_{32} & d_{33} & d_{34} & d_{35} \end{vmatrix},$$

$$\bar{D} = (0.282, 0.252, 0.190, 0.275) \times \begin{vmatrix} 0.22 & 0.36 & 0.27 & 0.13 & 0.02 \\ 0.22 & 0.30 & 0.26 & 0.15 & 0.08 \\ 0.18 & 0.40 & 0.27 & 0.13 & 0.03 \\ 0.20 & 0.41 & 0.25 & 0.11 & 0.03 \end{vmatrix}$$

$$\bar{D} = (0.21, 0.36, 0.26, 0.13, 0.04)$$

With reference to equation 5, $\bar{D}$ represents the fuzzy evaluated matrix or the membership functions of the entire constructs of the procurement process (Level 1), which is employed to estimate the overall vulnerability index by multiplying through the grading system (j =1, 2, 3, 4, 5). The MF at level 1 is presented in Table 5.

[Insert Table 5 Here]

Again, after the derivation of $\overline{D}$ which can be regarded as MF at level one, the formula,

$$\sum_{k=1}^{5} \overline{D} \times V^{t} = (D'_1, D'_2, D'_3, D'_4, D'_5) \times (1,2,3,4,5)$$

is employed to compute for the OVI as presented below:

$$OVI_{overall} = [(0.21 \times 1) + (0.36 \times 2) + (0.26 \times 3) + (0.13 \times 4) + (0.04 \times 5)] = 2.43 \text{ (Low)}.$$

The overall vulnerability index was estimated to be 2.43, which indicates a low vulnerability index. Recall the linguistic interpretations for the grading system 1-5, where 1 represents very low, 2 = low, 3 = neutral, 4 = high and 5 = very high. Detailed discussions of the index systems for both the stages and the overall index are presented in the next section.

Discussions

Generally, per the OVI of the procurement process, the FSE results stipulate that the procurement process of Hong Kong projects is relatively less vulnerable to corruption. On the other hand, the results agree with the general postulation regarding the control of corruption in HK as well as the efficacy of its anti-corruption institution (i.e., the Independent Commission Against Corruption, ICAC). Moreover, even though corruption is regarded as a very clandestine activity, which is mostly unnoticeable, the approach adopted by the ICAC has led to the discovery of diverse forms of corrupt practices emanating from cases and complaints. This is, however, reflected in the modus operandi of procuring, constructing, and managing infrastructure projects. For example, according to Rooke and Wiehem (1999), one of the brilliant, outstanding successes with regards to corruption combat in Hong Kong is the Airport Core Program. A report by TI (1999) indicated that this program outlines how corruption can be curtailed even in most huge infrastructure projects. It is a typical exemplary success model in Hong Kong's infrastructure procurement. Factors contributing to the successes realized in HK will be studied in detail in this study and how developing countries can adapt to some of the principal measures used in both the procurement system and the execution of the project. The detailed explication of the four stages is conducted in the following section.

The Pre-Contract and Contract Phases

The pre-contract stage (PCS) comprises of activities commencing from the definition of projects' requirements through to the receipt of tenders as established in the literature. Categorically, the PCS construct obtained a vulnerability index of 2.38, which ranks third. Even though four out of six activities within this construct were observed to have received relatively lower ratings regarding their vulnerability levels, two key activities, namely obtaining necessary approvals and the solicitation of tenders, were recorded as the leading variables with moderately rated levels of VI.

Among all the stages captured under the procurement process, the contract stage was identified to be the construct with the highest vulnerability index (Figure 1). This stage is made up of five activities, namely pre-tender meetings to establish evaluation criteria, evaluating received tenders (to either approve or reject bids), selecting a suitable contractor, awarding the contract to the selected contractor, and lastly, the preparation and signing of contracts by the consenting parties involved. Among the overall 21 procurement activities, seven were identified to be moderately vulnerable, and out of these seven, three are found at the contract stage (CAS). The CAS is reported to be the most critical phase of the entire process regarding the issue of transparency. Thus, it is considered to be one of the crucial areas of concern where the maximum attention and efforts towards transparency are needed to ensure that proposed (yet to be constructed) projects are awarded to the most qualified, responsive, and capable contractors. The eternal triangle, which represents the objectives of every construction project (i.e., time, quality, and cost), is primarily determined or realized at this stage even though other activities captured under other stages have an appreciable effect on these objectives for every project (Chan and Owusu 2017). The success or failure of a project largely depends on the capability and the of the contractor to complete the project per the projects; objectives. Moreover, since most projects are competitive based, this activity is rendered vulnerable to corrupt practices as most competing contractors would want to go the extra mile to pay any price to be awarded the project (Søreide, 2002). The dynamism and evolution of the variants of corruption are highly attributed to the unique mechanisms instigated by corrupt project officials who join forces to conspire different means of distorting the process to their favor (Olken 2007). Being the most vulnerable and critical stage when it comes to corruption, the results affirm the supposition why most anti-corruption frameworks are geared towards the expurgation of bribery acts. A typical example is the Anti-bribery management systems (ISO 37001) (GIACC 2016).

Contract Administration and Post-contract Phase

As the name implies, this stage is considered as the procurement phase, where the awarded contract is managed, and it can also be termed as the contract management stage (Concord 2018). The activities under this construct, therefore, include the issuance of contract amendments, monitoring the progress of work execution, following up on delivery, and the interim administration of progress payments (Ruparathna and Hewage, 2013). Following the contract stage, the contract management stage emerged as the second leading construct with high VI. Even though it is made up of four activities, administering progress payments was the sole activity or variable that was revealed to be moderately vulnerable with a mean index of 2.55, while the remaining three were revealed to be less vulnerable. Analogous to the other less vulnerable constructs, there is the need to strategize measures to sustain and enhance transparency throughout the stages.

Lastly, the Post-Contract Phase (PCP) ends the procurement process. It encapsulates the activities which ensure whether proposed projects have been executed within the prescribed specifications (quality, time, and budget) to enable the closing out of the contract (Lester, 2007). The activities captured under this construct are filing of final action contractor agreement to final claim, issuing any final amendments that were executed during the during the contract administration stage, ensuring the completeness of financial audits, checking for proofs of delivery (or checking whether works executed are as specified), the return of performance bonds and closing out on the contract after defects liability period is duly over and lastly, ensuring that all documentations are complete and accurate (Ruparathna and Hewage, 2013). Unlike the other stages, the PCP construct had the variables with relatively lower VIs making it the construct with the least VI. However, among the six activities, the respondents indicated PP16 to be moderately vulnerable, making it the top-rated activity with the highest VI.

Limitations and Recommendations for Future Research

While this study achieved the established objectives, some limitations were encountered. First, the results obtained apply only to the case of Hong Kong and cannot be generalized to suit the cases of other contexts. Second, while the sample size is agreed to be statistically adequate for this study, it is recommended that future studies can solicit a relatively larger sample size and project-based data. Lastly, given the uniqueness of individual construction projects, future studies can also focus on conducting a project-based vulnerability index. This can contribute to ascertaining the vulnerabilities' disparities among different projects.

Conclusion

This paper presented a set of established stages with their associated set of activities encapsulated within each stage of the procurement process using the fuzzy synthetic (FSE) evaluation approach to estimate the vulnerability indices (VI) of the stages (and respective activities) of the procurement process. The FSE technique was employed to minimize the skewness and fuzziness in qualitative views of experts that characterize decision making in real life (Ameyaw and Chan, 2015a). The assessments of the respective VIs were conducted towards the estimation of the procurement vulnerability index. Purposive sampling technique was employed to identify the potential respondents with expert knowledge on the dynamism of corruption in infrastructure procurement, and the FSE technique was employed to estimate all the three levels of indices commencing from the activities (Level 3), stages (Level 2) and lastly, the overall vulnerability index (Level 1). The OVI obtained was 2.43, which indicates that the procurement processes of projects in Hong Kong are less vulnerable to corrupt practices. However, even though a lower OVI was obtained, one out of the four procurement constructs labeled 'contract stage' was identified to be moderately vulnerable. The 21 activities are categorized into four distinct stages, namely the pre-contract stage, the contract stage, the contract administration state, and the post-contract stage (Lester, 2007; Ruparathna and Hewage, 2014). At level 3 (activities-level), seven out of the 21 activities were as well revealed to be moderately vulnerable to the incidences of corrupt practices, with CTS3 (selection of a contractor) being the activity with the highest vulnerability index. Unlike most cases in the developing context where the procurement stages and associated activities are predominantly prone to corrupt practices (for example, see Le et al. 2014a; Tabish and Jha 2011; Owusu et al. 2019), developed regions such as Hong Kong seem to have the situation under control even though there may be more room for improvement. This success can partly be attributed to the effectiveness of the existing ACMs stipulated to check corrupt practices in public sector activities, including public procurement of infrastructure-related works (Owusu et al. 2020). This study contributes to the widened understanding of the dynamics of corruption throughout the procurement process.

Data Availability Statement

Data on membership functions (MF) and expert surveys that support the findings of this study are available from the corresponding author upon reasonable request.

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APPENDIX

<u>Questionnaire Sample</u>

Q1. Vulnerability of procurement stages to corruption. How vulnerable are the following stages of procurement and construction to corruption? 1= Not vulnerable to 5=highly vulnerable. Please, also indicate the most extreme (only one) associated form to each process.

No	Procurement Process		Level of Vulnerability
1	Pre-Contract stage	Define requirements	☐1; ☐2; ☐3; ☐4; ☐5
2		Procurement process planning and strategy development	☐1; ☐2; ☐3; ☐4; ☐5
3		Pre-tender survey	☐1; ☐2; ☐3; ☐4; ☐5
4		Obtaining necessary approvals	☐1; ☐2; ☐3; ☐4; ☐5
5		Soliciting tenders	☐1; ☐2; ☐3; ☐4; ☐5
6		Receipt of tenders	☐1; ☐2; ☐3; ☐4; ☐5
7	Contract Stage	Pre-tender meeting (Establishing Evaluation Criteria, Evaluation Plan, Evaluation Criteria: Points or Adjectives)	☐1; ☐2; ☐3; ☐4; ☐5
8		Tender evaluation (review to approve or reject bids)	☐1; ☐2; ☐3; ☐4; ☐5
9		Select contractor	☐1; ☐2; ☐3; ☐4; ☐5
10		Award contract/Purchase order	☐1; ☐2; ☐3; ☐4; ☐5
11		Preparation and Signing of Contract	☐1; ☐2; ☐3; ☐4; ☐5
12	Contract administration stage	Issuing contract amendments	☐1; ☐2; ☐3; ☐4; ☐5
13		Monitor Progress	☐1; ☐2; ☐3; ☐4; ☐5
14		Follow up delivery	☐1; ☐2; ☐3; ☐4; ☐5
15		Administer Progress payments	☐1; ☐2; ☐3; ☐4; ☐5
16	Post contract phase	File final action Contractor agreement to final claim	☐1; ☐2; ☐3; ☐4; ☐5
17		Issue final contract amendment	☐1; ☐2; ☐3; ☐4; ☐5
18		Complete of financial audits	☐1; ☐2; ☐3; ☐4; ☐5
19		Check for proof of delivery	☐1; ☐2; ☐3; ☐4; ☐5
20		Return of performance bonds and close-out	☐1; ☐2; ☐3; ☐4; ☐5
21		Ensure completeness and accuracy of file documentation	☐1; ☐2; ☐3; ☐4; ☐5

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Table 1: Activities and Stages of the Procurement Process

No		Procurement Process	Code
1	Pre-Contract stage (PCS)	Define requirements	PCS1
2		Procurement process planning and strategy development	PCS2
3		Pre-tender survey	PCS3
4		Obtaining necessary approvals	PCS4
5		Soliciting tenders	PCS5
6		Receipt of tenders	PCS6
7	Contract Stage (CTS)	Pre-tender meeting (Establishing Evaluation Criteria, Evaluation Plan, Evaluation Criteria: Points or Adjectives)	CTS1
8		Tender evaluation (review to approve or reject bids)	CTS2
9		Select contractor	CTS3
10		Award contract/Purchase order	CTS4
11		Preparation and Signing of Contract	CTS5
12	Contract administration stage (CAS)	Issuing contract amendments	CAS1
13		Monitor Progress	CAS2
14		Follow up delivery	CAS3
15		Administer Progress payments	CAS4
16	Post contract phase (PCP)	File final action Contractor agreement to final claim	PCP1
17		Issue final contract amendment	PCP2
18		Complete of financial audits	PCP3
19		Check for proof of delivery	PCP4
20		Return of performance bonds and close-out	PCP5
21		Ensure completeness and accuracy of file documentation	PCP6

Reference: Ruparathna and Hewage (2013); Lester (2007)

Table 2: Summary of Respondents Profile

Measurement Item	*Frequency*	*Percent*	*Cumulative Percent*
Professional Affiliation			
Public	32	84.2	84.2
Private	4	10.5	94.7
Both	2	5.3	100.0
Total	**38**	**100.0**	
Professional Background			
Engineer	14	36.8	36.8
Quantity surveyor	10	26.3	63.2
Contractor	3	7.9	71.1
Academics	2	5.3	76.3
Architect	6	15.8	92.1
Others	3	7.9	100.0
Total	**38**	**100.0**	
Years of Experience			
Up to 10 years	15	39.47	39.47
11-20 years	5	13.16	52.63
21-40years	18	47.37	100
Total	**38**	**100.0**	

Source: Field Data

Table 3: Stages of the Procurement Process

No	Procurement Process	Code	Mean	Weighting	N-Value	Total mean	Weighting (wi)
1	Pre-Contract stage	PCS1	2.42	0.169	0.44		
2		PCS2	2.32	0.162	0.33		
3		PCS3	2.45	0.171	0.47		
4		PCS4	2.34	0.164	0.35		
5		PCS5	2.45	0.171	0.47		
6		PCS6	2.32	0.162	0.33	14.29	0.282
7	Contract Stage	CTS1	2.32	0.181	0.33		
8		CTS2	2.68	0.21	0.73		
9		CTS3	2.92	0.228	1		
10		CTS4	2.53	0.198	0.56		
11		CTS5	2.34	0.183	0.35	12.79	0.252
12	Contract administration stage	CAS1	2.32	0.24	0.33		
13		CAS2	2.39	0.249	0.4		
14		CAS3	2.37	0.246	0.38		
15		CAS4	2.55	0.265	0.58	9.63	0.19
16	Post contract phase	PCP1	2.58	0.185	0.62		
17		PCP2	2.42	0.174	0.44		
18		PCP3	2.42	0.174	0.44		
19		PCP4	2.32	0.166	0.33		
20		PCP5	2.03	0.145	0		
21		PCP6	2.18	0.157	0.17	13.95	0.275
						50.66	1

Table 4: Stages of the Procurement Process

Procurement Process (TS[a])	Code	Weighting	MF for Level 3	MF for Level 2
Pre-Contract stage	PCS1	0.169	0.16, 0.39, 0.34, 0.08, 0.03	0.22, 0.36, 0.27, 0.13, 0.02
	PCS2	0.162	0.21, 0.42, 0.26, 0.05, 0.05	
	PCS3	0.171	0.13, 0.47, 0.24, 0.13, 0.03	
	PCS4	0.164	0.26, 0.26, 0.34, 0.13, 0.00	
	PCS5	0.171	0.24, 0.26, 0.32, 0.18, 0.00	
	PCS6	0.162	0.32, 0.32, 0.13, 0.21, 0.03	
Contract Stage	CTS1	0.181	0.21, 0.42, 0.24, 0.11, 0.03	0.22, 0.30, 0.26, 0.15, 0.08
	CTS2	0.210	0.21, 0.24, 0.29, 0.18, 0.08	
	CTS3	0.228	0.21, 0.13, 0.32, 0.21, 0.13	
	CTS4	0.198	0.24, 0.29, 0.26, 0.13, 0.08	
	CTS5	0.183	0.21, 0.45, 0.18, 0.11, 0.05	
Contract administration stage	CAS1	0.240	0.18, 0.50, 0.16, 0.13, 0.03	0.18, 0.40, 0.27, 0.13, 0.03
	CAS2	0.249	0.16, 0.45, 0.26, 0.11, 0.03	
	CAS3	0.246	0.21, 0.37, 0.29, 0.11, 0.03	
	CAS4	0.265	0.18, 0.29, 0.34, 0.16, 0.03	
Post contract phase	PCP1	0.185	0.18, 0.29, 0.32, 0.18, 0.03	0.20, 0.41, 0.25, 0.11, 0.03
	PCP2	0.174	0.21, 0.34, 0.32, 0.08, 0.05	
	PCP3	0.174	0.18, 0.42, 0.24, 0.11, 0.05	
	PCP4	0.166	0.18, 0.42, 0.29, 0.11, 0.00	
	PCP5	0.145	0.21, 0.61, 0.13, 0.05, 0.00	
	PCP6	0.157	0.26, 0.45, 0.16, 0.11, 0.03	

Note: TS. Grouping Variable: Contextual groups (i.e., developed and developing countries)

b. Results indicating significant differences (Data with significant results)

* represents data with significant results; Sta* represents U statistics; W* represents Wilcoxon W; SD represents standard deviation.

Table 5: Stages of the Procurement Process

No	Procurement Process (TS[a])	Weighting	MF for Level 2	MF for Level 1
1	Pre-Contract stage	0.282	0.22, 0.36, 0.27, 0.13, 0.02	**0.21, 0.36, 0.26, 0.13, 0.04**
2	Contract Stage	0.252	0.22, 0.30, 0.26, 0.15, 0.08	
3	Contract Admin.	0.190	0.18, 0.40, 0.27, 0.13, 0.03	
4	Post contract phase	0.275	0.20, 0.41, 0.25, 0.11, 0.03	