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QUOTATION IMPACT FACTORS FOR GENERAL CONTRACTORS: A VIEWPOINT FROM PRIVATE SECTORS IN TAIWAN

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Abstract. The quotes provided by private sector entities to the project's general contractor vary based on actual considerations. This research aims to identify the factors that influence these quotes for general contractors. Through an extensive review of literature and interviews with experts, four main aspects were identified, encompassing a total of 38 impact factors related to quoting patterns. A survey was conducted among construction professionals, resulting in 123 valid responses out of 146 distributed surveys. The survey's validity was confirmed with a Cronbach's Alpha value exceeding 0.7. Subsequently, a factor analysis was performed, confirming 38 impact factors and their respective weights. The results from the Principal Component Analysis (PCA) offer valuable managerial insights, highlighting the most impactful factors: external demand, corporate adjustment, and financial condition. These findings provide practical guidance for practitioners. These insights encompass areas such as information sharing, project limitations, and subcontractor capabilities. Contrary to stereotypes presented in prior research, factors such as reputation and social connections were found to not significantly impact quotation outcomes.

Keywords: quotation factor, construction management, subcontractor, survey, PCA.

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1. Introduction

In various industries, professionals typically engage in contract quotation prior to commencing their tasks. In the realm of construction, this practice gains exceptional significance due to the substantial sums involved and the intricate cashflows typically associated with construction projects. Given the extensive nature of construction projects, which entail numerous intricate work items and activities, the process of quotation exchange between contractors and sub-contractors can evolve into a laborious endeavor, subject to practical considerations that significantly impact their financial gains (Shi et al., 2023; Tserng & Lin, 2002). In recent years, there has been an increasing diversity in bidding methods. While many subcontractors engage in bargaining considerations with profitability as their starting point, it is undeniable that various factors continue to impact the entire bargaining process, leading to instability in negotiations between contractors and subcontractors (Fu & Luo, 2023; An et al., 2018; Zhang et al., 2016; Chi & Mackay, 2015).

For the majority of non-government-contracted projects, contractors engage in a back-and-forth quotation process with various subcontractors when bidding on work items. Through this process, it becomes evident that different subcontractors exhibit varying trends in pricing behavior based on their respective company affiliations or contexts (Afshar et al., 2022; Karaman & Sandal, 2022; Lopez et al., 2017; Priven & Sacks, 2016; Manu et al., 2013). These distinct pricing behaviors also exert influence on project execution, underscoring the significant importance that each contractor places on selecting subcontractors with appropriate pricing practices. As projects grow in scale and become increasingly subdivided, the need for quotations arises more frequently (Tang et al., 2020, 2023). From the contractor's perspective, understanding the influencing factors of subcontractor pricing behavior holds great significance. This understanding aids in establishing relevant standards for selecting quotation-seeking vendors during bidding processes, and systematically analyzing subcon-

tractors' pricing behaviors through these influencing factors. Additionally, it assists estimators in achieving more accurate cost estimates for projects, ultimately contributing to the improvement of overall project objectives in terms of time, cost, quality, and team communication.

The objective of this research is to identify and rank the factors that exert influence over the quotation process for general contractors. This investigation concentrates on the private construction sector and its projects, as they differ significantly in quotation considerations from public sectors and projects, which must adhere to Taiwan's Procurement Laws. The methodology involves a 5-point Likert scale questionnaire survey, following the measurement approach recommended by Su et al. (2022), Chen et al. (2021), and Chen et al. (2020a). The survey targets seasoned construction professionals with at least ten years of experience.

2. Literature review

2.1. Contracting in construction

Collaboration among a multitude of professionals is essential in the realization of most construction projects, ensuring alignment with the owner's requirements. Throughout the project's execution, contractual agreements establish bindings among these professionals. Each contracting party fulfills their respective roles as outlined in these contracts (Wang et al., 2023; Fridkin & Kordova, 2022; Sodangi et al., 2018; Tam et al., 2011; Ulubeyli et al., 2010; Arditi & Chotibhongs, 2005). The value of these agreements ranges from thousands to billions of dollars, and this scope is expanding in tandem with the growing complexity of construction projects. In this context, the identification of suitable contractors is of paramount importance. These contractors must offer viable contractual terms and reasonable pricing for each procurement, contributing significantly to the overall success of the project. To attain these goals, the practice of seeking quotations from private sector entities in Taiwan is widely adopted (Zhang et al., 2020).

Quoting for construction projects serves as a crucial mechanism for securing favorable contract prices, services, and aligning expectations. However, the dynamics between contract parties often assume opposing stances as each seeks to optimize their own advantages. The process of quotation entails regular instances of bargaining and negotiation. Numerous factors exert influence over this process, with past research highlighting four significant dimensions: market environment, contractor status, subcontractors' considerations, and project-specific conditions (Chen et al., 2023; Lew et al., 2018; Yin et al., 2014; Choudhry et al., 2012; Chiang, 2009; Arditi & Chotibhongs, 2005). In relation to the market environment, four distinct factors associated with cost considerations significantly impact construction project quotations: logistical costs, material expenses, labor costs, and labor productivity (De Silva et al., 2017; Loosemore, 2016; Arditi & Chotibhongs, 2005). Contractor status, as another dimension, encompasses a broader array of considerations. These include corporate strategy, material availability, ongoing project volume, performance efficiency, past successful experiences, technical demands, project requirements, bid preparation costs, manpower availability, and the volume of quotations (Stadnicka & Ratnayake, 2018; Loosemore, 2016; Yin et al., 2014; Arditi & Chotibhongs, 2005; Tserng & Lin, 2002).

Subcontractors, similarly, harbor their own reservations when determining whether to engage in quotation processes with general contractors. Seven pertinent factors influence their decision-making, encompassing quotation frequency, competitive landscape, information accessibility, financial stability, inflation rates, successful past experiences, and bid incentives (Karaman & Sandal, 2022; Stadnicka & Ratnayake, 2018; Ulubeyli et al., 2010; Arditi & Chotibhongs, 2005; Tserng & Lin, 2002). While some of these factors overlap with those considered by contractors, the perspectives and considerations differ. Lastly, the factors within the context of project-specific conditions are intricate and widely varied, heavily contingent upon individual project circumstances. These encompass elements such as design feasibility, constructability, site location, contractual amounts, types of activities, activity pricing, activity durations, construction area size, number of building stories, number of basement stories, material quantities, roof types, hydrologic conditions, soil conditions, and the surrounding context (Afshar et al., 2022; Chiang, 2009; Stadnicka & Ratnayake, 2018; Chi & Mackay, 2015; Choudhry et al., 2012; Arditi & Chotibhongs, 2005).

2.2. PCA applications in construction

PCA is a widely utilized tool across various fields for handling questionnaire surveys (Gao et al., 2019; Chen et al., 2020b; Xue et al., 2021). It serves as a statistical analysis method aimed at simplifying datasets. Employing orthogonal transformation, it linearly converts observations of potentially related variables into a set of linearly uncorrelated variables, termed principal components. These principal components can be understood as linear equations featuring a series of linear coefficients indicating the projection direction. It's worth noting, as highlighted by Chen et al. (2014), that PCA's effectiveness is contingent upon the normalization or preprocessing of the original data. Within the construction industry, PCA has been extensively employed in research endeavors. It serves as a tool for extracting valuable insights such as market demand assessment, customer satisfaction analysis, facility management strategy formulation, corporate financing examination, quality assurance evaluation, and more, as evidenced by Nguyen et al. (2023), Chen et al. (2021), Han and Bogus (2021). Scholars suggest utilizing PCA for topics involving Likert scale questionnaire surveys ranging from 5 to 9 scales, typically favoring 5 scale surveys, as recommended by Ji et al. (2021), Wang et al. (2024), Romo et al. (2024).

3. Methodology

The formulation of the questionnaire aligns with the outlined aspects and factors, targeting distribution among experienced practitioners within the construction industry. Table 1 provides an overview of the quotation literature review, delineating each aspect. The review encompasses four key dimensions: market environment (ME), contractor status (CS), subcontractors' status (SS), and project condition (PC), collectively encompassing 38 distinct factors. ME refers to factors arising from external price fluctuations or significant environmental changes. CS represents the company itself, which implements strategies for internal operations or project acquisition in the course of undertaking construction projects. SS encompasses the additional project conditions provided by contractors in the budget proposal, as well as the contractors' reputation and payment records from previous projects, when submitting bids and pricing to the client. PC pertains to the conditions specific to the project itself during negotiation. Table 2 concisely encapsulates the names of these factors along with their corresponding descriptions, as extracted from the literature review.

Based on Table 2 and recommendation from the previous studies in the literature view section, a 5-point Likert scale questionnaire survey is suggested for practitioners with over 10 years of relevant experience (Ji et al., 2021). According to 95% confidence limits, a 40–60 category proportion, and a 10% margin of error, the minimum number of effective returns should be greater than 92 (Chen & Hsu, 2008). The survey process took approximately six months from distribution to return. Out of 140 questionnaires distributed, 123 effective responses were received, meeting the statistical criteria. The majority of the returns are male practitioners forming 84.6% of the total. The education background for the responders explicates that those professionals involving in quotation are well-educated with college or higher degrees at 90.2% of the total.

Table 1. Summary and clarification for quotation aspects

Aspect	Definition
Market environment (ME)	Factors resulting from external price fluctuations or significant environmental changes.
Contractor's status (CS)	The company itself that has strategies in place for internal operations or project acquisition in undertaking construction projects.
Subcontractors' status (SS)	The additional project conditions provided by contractors in the budget proposal and the reputation and payment records of contractors in previous projects when submitting bids and pricing to the client.
Project condition (PC)	The conditions encompassed within the project itself during negotiation.

Table 2. Factor descriptions

	Factor name	Supported literature
ME	Logistic cost	De Silva et al. (2017), Loosemore (2016), Arditi and Chotibhongs (2005)
	Material cost	Loosemore (2016), Arditi and Chotibhongs (2005)
	Labor cost	De Silva et al. (2017), Loosemore (2016), Arditi and Chotibhongs (2005)
	Labor productivity	Arditi and Chotibhongs (2005)
CS	Corporate strategy	Loosemore (2016), Yin et al. (2014), Tserng and Lin (2002)
	Material sufficiency	Stadnicka and Ratnayake (2018), Yin et al. (2014), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Total project quantity	Stadnicka and Ratnayake (2018), Loosemore (2016), Yin et al. (2014), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Construction efficiency	Stadnicka and Ratnayake (2018), Yin et al. (2014), Tserng and Lin (2002)
	Successful experience	Stadnicka and Ratnayake (2018), Loosemore (2016), Arditi and Chotibhongs (2005)
	Key techniques	Stadnicka and Ratnayake (2018)
	Project demand	Loosemore (2016), Yin et al. (2014), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Bid preparation cost	Stadnicka and Ratnayake (2018), Loosemore (2016), Yin et al. (2014), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Manpower sufficiency	Stadnicka and Ratnayake (2018), Arditi and Chotibhongs (2005)
	Quotation frequency	Stadnicka and Ratnayake (2018), Yin et al. (2014), Tserng and Lin (2002)
SS	Inquiry frequency	Stadnicka and Ratnayake (2018), Ulubeyli et al. (2010), Arditi and Chotibhongs (2005)
	Competitor number	Karaman and Sandal (2022), Stadnicka and Ratnayake (2018), Ulubeyli et al. (2010), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Information accuracy	Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Financial health	Karaman and Sandal (2022), Stadnicka and Ratnayake (2018), Ulubeyli et al. (2010), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Inflation adjustment	Stadnicka and Ratnayake (2018), Ulubeyli et al. (2010)
	Successful experience	Karaman and Sandal (2022), Stadnicka and Ratnayake (2018), Ulubeyli et al. (2010), Arditi and Chotibhongs (2005), Tserng and Lin (2002)
	Bid terms	Arditi and Chotibhongs (2005)

End of Table 2

	Factor name	Supported literature
PC	Design	Afshar et al. (2022), Stadnicka and Ratnayake (2018), Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Construction-ability	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Chi and Mackay (2015), Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Regional condition	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018)
	Item quantity	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Choudhry et al. (2012)
	Project type	Chiang (2009), Chi and Mackay (2015), Choudhry et al. (2012)
	Project amount	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Chi and Mackay (2015), Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Project duration	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Arditi and Chotibhongs (2005)
	Project area	Arditi and Chotibhongs (2005)
	Floor number	Afshar et al. (2022), Stadnicka and Ratnayake (2018), Chi and Mackay (2015)
	Material quantity	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Chi and Mackay (2015), Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Roof type	Choudhry et al. (2012)
	Basement number	Afshar et al. (2022), Stadnicka and Ratnayake (2018), Chi and Mackay (2015)
	Hydrological environment	Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Soil condition	Chi and Mackay (2015), Choudhry et al. (2012), Arditi and Chotibhongs (2005)
	Surrounding condition	Afshar et al. (2022), Chiang (2009), Stadnicka and Ratnayake (2018), Chi and Mackay (2015), Choudhry et al. (2012), Arditi and Chotibhongs (2005)

Based on recommendations from previous studies (Ji et al., 2021; Chen et al., 2020a; Chen & Hsu, 2008), SPSS software was apt and used to conduct PCA and factor analysis, yielding the following findings. Factor analyses were performed for each aspect individually.

4. Results and discussion

4.1. Results from PCA analysis

The reliability for the survey has Cronbach' s α = 0.817 (>0.7 acceptable) and Kaiser-Meyer-Olkin (KMO) = 0.822 (>0.6 acceptable) presenting a successful survey investigation (Chen & Hsu, 2008). Through the utilization of PCA, the factors with eigenvalues >1 in the aspects are considered. Starting with Aspect ME, the factors were combined into a single factor, also labeled according to the aspect in Table 3. In the case of Aspect CS, a post-transformation component matrix revealed three components: corporate adjustment, sub capacity, and quotation terms, as outlined in Table 4. Within Aspect SS, three components were identified: experience record, financial condition, and inflation, elucidated in Table 5. After undergoing transformation, the component matrix merged the factors within Aspect PC into four components: project condition, project surroundings, internal demand, and external demand, as showcased in Table 6. Additionally, preference rankings for the aforementioned aspects and factors were furnished. These preference rankings for aspects and their corresponding factors are presented in Table 7. Based on the PCA results and illustrated eigenvalues, Tables 3 to 6 present the derived importance rankings for each dimension and the importance rankings for the subcategories following factor analysis. From the initial 38 factors, 11 pivotal factors were identified that significantly influence subcontractor quotation patterns.

The critical factors influencing bargaining behavior between contractors and subcontractors do not exhibit significant distinctions. Subcontractors' reliance is primarily upon internal company resources. Due to their exemption from assuming the full extent of project risks, subcontractors are particularly concerned with the accurate and timely receipt of payments. As evidenced by the average ratings falling within the range of 3 to 4 shown in Table 7, factors such as contractor's financial records and contractor's experience records hold a moderate to significant level of importance for subcontractors. An observed distinctive data disparity is identified when subcontractors assess the situation of the contracting company. In this regard, the inclusion or absence of a price fluctuation index within the contract terms is not deemed a significant factor by subcontractors. Moreover, the contractual duration and scope of work are not as extensive for subcontractors as they are for contractors undertaking complete project responsibility. The impact of price fluctuation index on their interests is comparatively limited. This also indirectly reflects that subcontractors place greater emphasis on the conditions of their designated scope rather than the comprehensive nature of the entire project. This characteristic is manifested in the project conditions section, where subcontractors regard key factors related to project design as more significant.

Table 3. Factor loading after rotation for Aspect ME

	Renamed factor	Factor	Factor loading	Explained variation
ME	Market price	Material cost	0.851	63.02% (eigenvalue = 1.89)
		Labor cost	0.778	
		Labor productivity	0.749	
	Total explained variation	63.02%		

Table 4. Factor loading after rotation for Aspect CS

	Renamed factor	Factor	Factor loading	Explained variation
CS	Corporate adjustment	Corporate strategy	0.782	37.52% (eigenvalue = 1.97)
		Material sufficiency	0.747	
		Total project quantity	0.663	
		Construction efficiency	0.604	
	Sub capacity	Project demand	0.834	13.12% (eigenvalue = 1.27)
		Key techniques	0.759	
	Quotation terms	Quotation frequency	0.807	12.25% (eigenvalue = 1.23)
		Manpower sufficiency	0.758	
	Total explained variation	62.90%		

Table 5. Factor loading after rotation for Aspect SS

	Renamed factor	Factor	Factor loading	Explained variation
SS	Experience record	Successful experience	0.951	40.71% (eigenvalue = 1.50)
		Information accuracy	0.774	
	Financial condition	Financial health	0.849	23.62% (eigenvalue = 1.40)
		Bid term	0.836	
	Inflation	Inflation adjustment	0.997	15.46% (eigenvalue = 1.00)
	Total explained variation	79.78%		

Table 6. Factor loading after rotation for Aspect PC

	Renamed factor	Factor	Factor loading	Explained variation
PC	Project condition	Design	0.751	27.42% (eigenvalue = 1.98)
		Project duration	0.734	
		Project amount	0.682	
		Construction-ability	0.643	
	Project surroundings	Hydrological environment	0.832	14.46% (eigenvalue = 2.17)
		Soil condition	0.772	
		Basement number	0.714	
		Surrounding condition	0.623	
	Internal demand	Floor number	0.808	11.02% (eigenvalue = 1.88)
		Roof type	0.693	
		Material quantity	0.632	
		Project area	0.596	
	External demand	Regional condition	0.756	8.05% (eigenvalue = 1.10)
		Item quantity	0.733	
	Total explained variation	60.96%		

Table 7. Preference ranking for aspects and factors

	ME (Average)	CS (Average)	SS (Average)	PC (Average)
Factors	Market price (3.29)	Corporate adjustment (3.345)	Financial condition (3.3)	External demand (3.41)
		Sub capacity (3.24)	Experience record (3.28)	Project condition (3.28)
		Quotation terms (3.15)	Inflation (3.12)	Internal demand (3.13)
				Project surroundings (2.82)

Table 7 implies that, in a broader context, it can be discerned that contractors and subcontractors exhibit relatively minor disparities in their considerations of bargaining behavior. The focal aspects they prioritize are not markedly distinct. However, divergences primarily manifest in the ranking of importance. Contractors tend to place greater emphasis on whether undertaking a project can yield additional profits or associated benefits. In contrast, subcontractors primarily concentrate on the successful execution of ongoing tasks and the attainment of contractually stipulated rewards within the specified timeframe.

4.2. Discussion and managerial implications

The implication for each aspect based on the result can be expressed as follows:

(1) The management implications of ME: When subcontractors are preparing their quotes and comparing market factors, their primary consideration is material cost fluctuations (mean: 3.41). This is because, during construction, the supply of materials largely falls under the subcontractor's responsibilities, and the quantity of materials required surpasses that of labor or machinery. Thus, it is the foremost factor in their pricing behavior. The second consideration is labor cost fluctuations (mean: 3.28), with its mean being very close to that of labor productivity (mean: 3.18). Since both of these control factors are related to the value and cost of labor available in the current market, subcontractors place a high importance on these factors, above the average value. In construction, the quality and cost of workers are crucial for a successful project, hence fluctuations in wage prices significantly impact subcontractors who maintain a certain quality standard.

(2) The management implications of CS: In the analysis of factors affecting the bidding behavior of subcontractors based on their company's internal situation, it is evident that when subcontractors decide on their bidding strategy, their primary consideration is whether they can successfully complete the tasks assigned by the contractor. This takes precedence over the company's current strategies or project volume. After all, having the capability to undertake the project is essential to negotiating with the contractor and maximizing their own benefits. This priority is reflected in the factor analysis ranking, where the alignment between the contractor's and subcontractor's project requirements is more important than the company's internal adjustments or additional negotiations with the contractor. Furthermore, since this study focuses on subcontractors from Class A/B construction firms, the survey does not address the higher bid preparation costs associated with public project bidding processes. This is reflected in the data, showing that the subcontractors of sub-projects place less emphasis on bid preparation costs. Additionally, the number of negotiation rounds does not significantly impact the bidding behavior of subcontractors.

(3) The management implications of SS: In the consolidated analysis results of this study, the top two ranked factors under the subcontractor's company situation are related to its current or past financial status. The top factor is related to the contractor's financial situation, corroborating the earlier findings. This confirms that the contractor's financial status indeed has a strong influence on the subcontractor's negotiation behavior. This is also because the contractor's financial payment ability determines the upper limit of the subcontractor's bid. Understanding the contractor's financial capacity in advance can significantly influence the subcontractor's bidding behavior, potentially leading them to submit higher bids to maximize their profits. If the contractor's financial situation cannot meet the subcontractor's desired profit or cover the costs, the subcontractor may choose not to negotiate or adopt a passive approach during negotiations. Subcontractors may prefer to work with contractors who offer the highest profit potential to increase their own earnings. The lowest-ranked factor is "whether the price index fluctuations are accounted for in project pricing". This corresponds with the observation that subcontractors' bidding behavior is seldom affected by the number of negotiation rounds.

(4) The management implications of PC: The quantity of deliveries and regional factors occupy the first and second positions in importance, aligning with the rankings derived from factor analysis. This indicates that in the consideration of project conditions, the impact of delivery quantity and regional factors significantly influences subcontractors' bidding behavior. Different regions present diverse architectural styles and excavation requirements for foundations. The delivery quantity varies based on regional construction methods, affecting the negotiation process. Subcontractors might adjust the unit price of materials or labor based on the quantity required. The subsequent factors are "construction-ability", "project amount", and "project duration". These relate to the project's design specifications, indicating that pre-project planning affects subcontractors' willingness to negotiate. Factors such as whether the construction conditions are acceptable to subcontractors, or whether the project cost aligns with the contractor's financial capabilities, are crucial considerations during negotiations. Project duration impacts whether subcontractors can fit the project into their schedules; if not, they may increase their bid to accommodate the project timeline. The least influential factors, "soil conditions" and "hydrological environment", are both below the average significance. These natural conditions are issues that the contractor must address during project design. Subcontractors tend to overlook these factors, as they are only responsible for completing the specific tasks assigned by the contractor. Thus, considerations of the surrounding environmental conditions are less apparent in their bidding behavior.

5. Conclusions

The quotations submitted by private sector entities to the general contractor of a project exhibit notable variations driven by distinct considerations. The objective of this study is to meticulously delineate the factors exerting influence on these quotations within the purview of general contractors. In pursuit of this goal, an exhaustive exploration of existing literature was undertaken, complemented by insightful interviews with subject matter experts. This comprehensive inquiry yielded the identification of four overarching dimensions, collectively encapsulating a comprehensive collection of 38 distinct impact factors intricately linked to the intricacies of quoting behaviors. To empirically substantiate the significance of these factors, a survey was meticulously crafted and judiciously administered among a cohort of construction industry professionals. The survey deployment yielded a noteworthy response rate of 123 valid responses out of a total of 146 distributed surveys, indicative of a robust engagement with the research endeavor. Importantly, the survey instrument's internal consistency and reliability were verified through the calculation of Cronbach's Alpha, yielding an impressive coefficient exceeding the threshold of 0.8, thereby affirming the instrument's credibility and robustness. With a rich dataset of responses at hand, a meticulous factor analysis was executed, unearthing and confirming the existence of the previously identified 38 impact factors. Furthermore, the analysis astutely elucidated the respective weights of these factors, unraveling their relative significance in influencing the complex landscape of quotation determination. This intricate empirical exploration contributes substantively to our understanding of the multifaceted dynamics underpinning quoting behaviors within the construction industry, shedding light on the intricate interplay of these factors and their consequential effects on the broader project ecosystem.

The factors undergo consolidation into distinct components, which are subsequently assigned new names based on their preference rankings within the corresponding aspects: In Aspect ME, the factor becomes "market price"; in Aspect CS, the factors are labeled as "corporate adjustment", "sub capacity", "quotation terms", "financial condition", "project condition", and "inflation"; and in Aspect PC, the components are termed "external demand", "project condition", "internal demand", and "project surroundings". The primary disparities become evident in the hierarchical order of importance. Contractors exhibit a proclivity for prioritizing the assessment of a project's potential to generate additional profits or related advantages. In contrast, subcontractors concentrate predominantly on ensuring the successful completion of ongoing tasks and achieving stipulated contractual compensation within specified timeframes. This study concludes by highlighting: (1) the positive correlation of 31 out of 38 collected factors with the quotation process; (2) the varying degrees of influence of aspects and factors on construction quotation, as indicated by their preference rankings; and (3) practical recommendations aimed at enhancing the quotation process.

This study is to broadly address the perceptions of most contractors regarding the influencing factors in their quotation behaviors, with a specific focus on analyzing the variations in factors affecting the quoting practices of construction firms. Given the diverse nature of subcontractors across different facets, such as assumptions, foundations, templates, machinery, and other distinct dimensions within construction projects, varying considerations at different professional levels are inevitable. Consequently, the factors influencing the quotation process may also diverge accordingly. To facilitate further research endeavors, it is imperative to expand the scope of study and broaden the sample size to encompass a more comprehensive array of experts from various specialized fields within the construction industry. This approach will enable a precise delineation of the impact factors and enhance the study's precision and applicability through an increased sample size. Moreover, given that the study focuses on Taiwan, it is crucial to consider the differences between Taiwan and other regions. This reflection will help determine the study's applicability and the broader relevance of its findings.

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Competing statement

The corresponding author declares that this paper has no conflict of interests to any other research or work.

Data availability statement

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

References

Afshar, M. R., Shahhosseini, V., & Sebt, M. H. (2022). Optimal subcontractor selection and allocation in a multiple construction project: Project portfolio planning in practice. *Journal of the Operational Research Society*, *73*(2), 351–364. https://doi.org/10.1080/01605682.2020.1835450

An, X. W., Li, H. M., Ojuri, O., Wang, Z. F., & Ding, J. Y. (2018). Negotiation model of design optimization profit distribution with fairness concerns in construction projects. *KSCE Journal of Civil Engineering*, *22*(7), 2178–2187. https://doi.org/10.1007/s12205-017-0190-0

Arditi, D., & Chotibhongs, R. (2005). Issues in subcontracting practice. *Journal of Construction Engineering and Management*, *131*(8), 866–876. https://doi.org/10.1061/(ASCE)0733-9364(2005)131:8(866)

Chen, J.-H., & Hsu, S.-C. (2008). Quantifying impact factors of corporate financing: Engineering consulting firms. *Journal of Management in Engineering*, *24*(2), 96–104. https://doi.org/10.1061/(ASCE)0742-597X(2008)24:2(96)

Chen, J.-H., Lin, J.-Z., & Hsu, S.-C. (2014). Determining and classifying factors of employees' expatriation willingness using rough set. *Journal of Management in Engineering*, *30*(5), Article 04014021. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000206

Chen, J.-H., Wei, H.-H., Chen, C.-L., Wei, H.-Y., Chen, Y.-P., & Ye, Z. (2020a). A practical approach to determining critical macroeconomic factors in air-traffic volume based on k-means clustering and decision-tree classification. *Journal of Air Transport Management*, *82*, Article 101743. https://doi.org/10.1016/j.jairtraman.2019.101743

Chen, J.-H., Nguyen, T. T., Tai, H.-W., & Chang, C.-A. (2020b). The willingness to adopt the Internet of Things (IoT) conception in Taiwan's construction industry. *Journal of Civil Engineering and Management*, *26*(6), 534–550. https://doi.org/10.3846/jcem.2020.12639

Chen, J.-H., Chou, T.-S., Wang, J.-P., Wei, H.-H., & Yang, T.-H. (2021). Sustainable corporate governance: The impact factors for top consulting engineering companies in Taiwan. *Sustainability*, *13*(14), Article 7604. https://doi.org/10.3390/su13147604

Chen, Z. Z., Zhu, W. S., & Crama, P. (2023). Subcontracting and rework cost sharing in engineering-procurement-construction projects. *International Journal of Production Economics*, *262*, Article 108118. https://doi.org/10.1016/j.ijpe.2023.108901

Chiang, Y. H. (2009). Subcontracting and its ramifications: A survey of the building industry in Hong Kong. *International Journal of Project Management*, *27*(1), 80–88. https://doi.org/10.1016/j.ijproman.2008.01.005

Chi, S., & Mackay, C. (2015). Negotiating subcontract conditions in the Australian construction industry. *KSCE Journal of Civil Engineering*, *19*(3), 485–497. https://doi.org/10.1007/s12205-013-0303-3

Choudhry, R. M., Hinze, J. W., Arshad, M., & Gabriel, H. F. (2012). Subcontracting practices in the construction industry of Pakistan. *Journal of Construction Engineering and Management*, *138*(12), 1353–1359. https://doi.org/10.1061/(ASCE)CO.1943-7862.0000562

De Silva, D. G., Kosmopoulou, G., & Lamarche, C. (2017). Subcontracting and the survival of plants in the road construction industry: A panel quantile regression analysis. *Journal of Economic Behavior & Organization*, *137*, 113–131. https://doi.org/10.1016/j.jebo.2017.02.016

Fridkin, S., & Kordova, S. (2022). Examining criteria for choosing subcontractors for complex and multi-systems projects. *Sustainability*, *14*(22), Article 14988. https://doi.org/10.3390/su142214988

Fu, Y. F., & Luo, Y. Y. (2023). The interaction effect of trust and contract on dispute negotiation strategy: Evidence from the Chinese construction industry. *International Journal of Conflict Management*, *34*(3), 570–597. https://doi.org/10.1108/IJCMA-10-2022-0161

Gao, W. T., Song, J. Y., & Guo, W. (2019). PCA model and case study for coastal highway construction projects. *Journal of Coastal Research*, *94*, 191–195. https://doi.org/10.2112/SI94-040.1

Han, F., & Bogus, S. M. (2021). Resilience criteria for project delivery processes: An exploratory analysis for highway project development. *Journal of Construction Engineering and Management*, *147*(11), Article 04021140. https://doi.org/10.1061/(ASCE)CO.1943-7862.0002179

Ji, T.-T., Wei, H.-H., Chen, J.-H., & Su, Y.-C. (2021). Towards people-centric smart city development: Investigating the citizens' preferences and perceptions about smart-city services in Taiwan. *Sustainable Cities and Society*, *67*, Article 102691. https://doi.org/10.1016/j.scs.2020.102691

Karaman, A. E., & Sandal, K. (2022). Effect of sub-contractor selection on construction project success in Turkey. *Teknik Dergi*, *33*(4), 12105–12118. https://doi.org/10.18400/tekderg.731728

Lew, Y. L., Hassim, S., Muniandy, R., & Hua, L. T. (2018). Structural equation modelling for subcontracting practice: Malaysia chapter. *Engineering, Construction and Architectural Management*, *25*(7), 835–860. https://doi.org/10.1108/ECAM-04-2017-0073

Loosemore, M. (2016). Social procurement in UK construction projects. *International Journal of Project Management*, *34*(2), 133–144. https://doi.org/10.1016/j.ijproman.2015.10.005

Lopez, R., Chong, H. Y., Moon, S., & Wang, X. Y. (2017). Case study on subcontracting arrangements in the scaffolding supply chain of a liquefied natural gas infrastructural project. *Journal of Civil Engineering and Management*, *23*(8), 1136–1147. https://doi.org/10.3846/13923730.2017.1388277

Manu, P., Ankrah, N., Proverbs, D., & Suresh, S. (2013). Mitigating the health and safety influence of subcontracting in construction: The approach of main contractors. *International Journal of Project Management*, *31*(7), 1017–1026. https://doi.org/10.1016/j.ijproman.2012.11.011

Nguyen, H. T. T., Wang, H.-H., & Chen, J.-H. (2023). Identifying the factors affecting the deployment of smart transportation in major cities of Vietnam. *Journal of the Chinese Institute of Civil and Hydraulic Engineering*, *35*(8), 815–824.

Priven, V., & Sacks, R. (2016). Impacts of the social subcontract and last planner system interventions on the trade-crew workflows of multistory residential construction projects. *Journal of Construction Engineering and Management*, *142*(7), Article 04016013. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001102

Romo, R., Alejo-Reyes, A., & Orozco, F. (2024). Statistical analysis of lean construction barriers to optimize its implementation using PLS-SEM and PCA. *Buildings*, *14*(2), Article 486. https://doi.org/10.3390/buildings14020486

Shi, C. X., Chen, Y. Q., Hua, Y. Y., & Tang, Y. Q. (2023). Understanding subcontracting organizational arrangements for construction projects in China: Integrating capabilities and uncertainty. *Engineering, Construction and Architectural Management*, *30*(6), 2381–2399. https://doi.org/10.1108/ECAM-11-2019-0631

Stadnicka, D., & Ratnayake, R. M. C. (2018). Development of additional indicators for quotation preparation performance management: VSM-based approach. *Journal of Manufacturing Technology Management*, *29*(5), 866–885. https://doi.org/10.1108/JMTM-01-2017-0016

Sodangi, M., Salman, A. F., & Saleem, M. (2018). Building information modeling: Awareness across the subcontracting sector of Saudi Arabian construction industry. *Arabian Journal for Science and Engineering*, *43*(4), 1807–1816. https://doi.org/10.1007/s13369-017-2756-z

Su, Y.-M., Chen, J.-H., Cheng, J.-Y., Hsu, Y.-T., & Huang, M.-C. (2022). Rough-set based association rules toward performance of high friction road markings. *Journal of Transportation Engineering, Part B: Pavements*, *148*(2), Article 05022001. https://doi.org/10.1061/JPEODX.0000355

Tam, V. W. Y., Shen, L. Y., & Kong, J. S. Y. (2011). Impacts of multi-layer chain subcontracting on project management performance. *International Journal of Project Management*, *29*(1), 108–116. https://doi.org/10.1016/j.ijproman.2010.01.005

Tang, Y. Q., Chen, Y. Q., Hua, Y. Y., & Fu, Y. C. (2020). Impacts of risk allocation on conflict negotiation costs in construction projects: Does managerial control matter?. *International Journal of Project Management*, *38*(3), 188–199. https://doi.org/10.1016/j.ijproman.2020.03.002

Tang, Y. Q., Chen, Y. Q., Arditi, D., & Meng, F. S. (2023). Effects of the general contractor's governance capabilities and project goals on the organizational arrangement of subcontracting. *IEEE Transactions on Engineering Management*, *70*(5), 1724–1737. https://doi.org/10.1109/TEM.2021.3064020

Tserng, H. P., & Lin, P. H. (2002). An accelerated subcontracting and procuring model for construction projects. *Automation in Construction*, *11*(1), 105–125. https://doi.org/10.1016/S0926-5805(01)00056-5

Ulubeyli, S., Manisali, E., & Kazaz, A. (2010). Subcontractor selection practices in international construction projects. *Journal of Civil Engineering and Management*, *16*(1), 47–56. https://doi.org/10.3846/jcem.2010.04

Wang, C. H., Zhang, S. B., Gao, Y., Guo, Q., & Zhang, L. (2023). Effect of contractual complexity on conflict in construction subcontracting: Moderating roles of contractual enforcement and organizational culture distance. *Journal of Construction Engineering and Management*, *149*(5), Article 04023019. https://doi.org/10.1061/JCEMD4.COENG-12822

Wang, Y. L., Zuo, J., Pan, M., Tu, B. C., Chang, R. D., Liu, S. C., Xiong, F., & Dong, N. (2024). Cost prediction of building projects using the novel hybrid RA-ANN model. *Engineering, Construction and Architectural Management*, *31*(6), 2563–2582. https://doi.org/10.1108/ECAM-07-2022-0666

Xue, Y., Chen, C., Wang, C. S., Li, L. G., & Mansour, R. F. (2021). Face image compression and reconstruction based on improved PCA. *Intelligent Automation and Soft Computing*, *30*(3), 973–982. https://doi.org/10.32604/iasc.2021.017607

Yin, S. Y. L., Tserng, H. P., Toong, S. N., & Ngo, T. L. (2014). An improved approach to the subcontracting procurement process in a lean construction setting. *Journal of Civil Engineering and Management*, *20*(3), 389–403. https://doi.org/10.3846/13923730.2013.801900

Zhang, S. B., Fu, Y. F., Gao, Y., & Zheng, X. D. (2016). Influence of trust and contract on dispute negotiation behavioral strategy in construction subcontracting. *Journal of Management in Engineering*, *32*(4), Article 04016001. https://doi.org/10.1061/(ASCE)ME.1943-5479.0000427

Zhang, S. B., Chen, J. Y., & Fu, Y. F. (2020). Contract complexity and trust in construction project subcontracting. *Engineering, Construction and Architectural Management*, *27*(9), 2477–2500. https://doi.org/10.1108/ECAM-02-2019-0113