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ScienceDirect

Procedia Manufacturing 51 (2020) 1703–1708

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

30th International Conference on Flexible Automation and Intelligent Manufacturing (FAIM2021)
15-18 June 2021, Athens, Greece.

Supplier pre-qualification method for the Portuguese construction industry

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Abstract

The construction process is so dependent on supply chain partners that selecting the best ones has an impact on its performance. The literature on supplier selection in the construction industry is little explored and its proposals are complex using techniques that industry managers are unfamiliar. This work's purpose was to study a construction organization's needs and, thus, develop a method of supplier qualification, capable of matching best practices while responding to the company's specific needs, according to its context. Thereby, a case study was used in the metal construction industry. The paper describes the development of a simple and fast supply chain partner pre-qualification method, which corresponds to a questionnaire, an automatic assessment, and a classification method. The study' main conclusions are the managers' lack of familiarity with analysis and improvement techniques, the difficulty of defining "quality" in this industry and the need for further studies in this area.

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Peer-review under responsibility of the scientific committee of the FAIM 2021.

Keywords: Pre-qualification method; pre-qualification process; subcontractors; supplier selection; suppliers.

1. Introduction

The construction industry (CI) is a relevant segment for the world economy and is characterized by being a complex sector, with adverse "buyer-supplier" relationships, and low-performance levels. It is distinguished from other industries essentially because it is based on discontinuous complex projects where multiple independent organizations participate in fragmented business processes to deliver a single product, whose production is wholly or partially carried out at the place of use. Accordingly, the implementation of construction projects is considered to be carried out by a temporary ad hoc organization [1, 2]. To improve its internal and external efficiency, reduce waste, add value through its supply chain while remove its adverse relationships and fragmented processes, manufacturing strategies such as Total Quality Management (TQM), Lean Thinking and Supply Chain Management (SCM) have been implemented [1, 3, 4]. Despite the potential of these strategies to improve performance levels in the CI, the results were not the expected benefits and even partial implementations of these strategies are mentioned [3 - 6]. The peculiar characteristics of the industry, namely the lack of standardization [3, 4], the involvement of multiple independent organizations [1, 3, 5], the lack of control of the value chain [4, 6], and the competitive bidding process [3, 7] are pointed out as obstacles to the success of these initiatives. Additionally, when investigating the root causes of construction project problems, [6] concluded that they were originated in previous process stages. Reinforcing this conclusion, [2] and [5] also associate the problems of this industry with supply chain partners. Considering that in construction projects approximately 90% of the work is done by subcontractors [8] and that 80% of the schedule is affected by suppliers [9], an effective supplier selection process is expected to contribute to improve industry performance levels through its indirect action assist in adapting improvement

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10.1016/j.promfg.2020.10.237

strategies to the CI, as it is expected to contribute directly to improving product quality and reducing delays.

The topic of supplier selection is widely explored in the manufacturing literature, especially through the development of selection tools and the study of supplier selection criteria [10]. However, the topic is not widely explored in the CI, and the few proposals use sophisticated techniques and tools, not familiar to Portuguese contractors and construction managers [11]. Additionally, their level of awareness of improvement techniques is low [12, 13]. Thus, this study aims to develop a solution for improving supplier and subcontractor control in the supplier selection process of a construction organization, in which the system and processes are still not mature, and their managers are unfamiliar with improvement techniques.

The work is divided into a literature review (section 2) where the supplier selection process is defined, and the state of the art of pre-qualification of subcontractors and suppliers in the CI is summarized. Section 3 presents the research methodology, followed by a detailed problem description and project requirements. Section 5 presents the development of the pre-qualification method. Finally, section 6 presents the conclusions of this study.

2. Literature review

Organizations cannot be competent, producing high quality at a low cost without a competent supply chain [14]. In the CI literature, authors recognize the importance of supplier selection [15, 16]. One of the characteristics of the CI is the use of material and equipment suppliers, but also specialized service providers (subcontractors). Construction progress is affected by both labor availability and resource availability [17]. While supplier performance may particularly influence project cost and timing [17], subcontractors' performance has been highlighted by influencing productivity and quality [18-20].

As organizations are becoming more dependent on suppliers, the consequences of bad decisions become severe. It is important to have a systematic supplier/subcontractor selection process using criteria to choose the supplier that supports the organization's strategy and approaches/methods to deal with the complexity of the situation (many different and possible suppliers, multiple decision-makers, incomplete information, uncertainty, etc.) [14, 21].

The supplier selection process comprises the steps: (i) defining the selection problem and strategic choice priorities, (ii) defining the criteria, (iii) prequalification of suppliers, and (iv) final selection. The difference between pre-qualification and selection is the difference between classification and sorting, respectively. Therefore, pre-qualification means reducing the set of all suppliers to a more manageable set by assigning a rating. On the other hand, the final selection means the choice of one supplier (or set of suppliers in case of multiple deliveries) from the options, that is, at this stage, there is the aggregation and order of supplier performance results with the strategic expectations of the contractor to select one [22].

According to [23], there are two types of criteria for evaluating suppliers: process-based and performance-based. The difference between these types of criteria lies in the fact that in process criteria the supplier's process capability is evaluated, while in performance evaluation criteria is intended to measure the supplier's current performance against given criteria.

This research only reviewed the work on the pre-qualification stage, specifically for the CI. This literature review was performed using the search engine Google Scholar and the databases Scopus and Science Direct, with the following keywords: Pre-qualification, Subcontractor, Supplier, Vendor, and Construction Industry. Section 2.1 presents the results found for the pre-qualification stage of subcontractors in the CI, and section 2.2 shows the results found for the pre-qualification stage of suppliers for the CI.

2.1. Subcontractors pre-qualification in the construction industry: criteria and methods

The literature has sought to study the pre-qualification of subcontractors in an attempt to control their performance in projects, as they are blamed for poor project outcomes. The first efforts in this direction were made by the Singapore and Hong Kong governments with the establishment of a centralized subcontractor registration system. In these, subcontractors to be invited to participate in the competitive bidding process need to have prior registration in this system, and only those whose characteristics were considered suitable for carrying out the project were invited to bid. The criteria used for pre-qualification of subcontractors varies:

- Previous experience; Quality; Compliance with regulations; Financial capacity; Progress; Communication; Contractual relationships; Type of specialized work; Environmental concerns; Experience of supervisors; Occupational safety; Amount of resources; Participation in the proposal phase; Design support [20];
- Quick response to design changes; Utilities (gas, water, etc.); Risk management; Number of previous projects; Fast response to contractor correspondence; Milestones compliance rate; Maintenance program; Occupational accident rate; Compliance with safety regulations; Compliance with environmental regulations; Number of senior staff; Relationship with the client and other subcontractors; Performance in other similar projects [24];
- Reputation; Organization history; Equipment performance; Planning; Team spirit; Team performance; Profit; Profit growth; Political situation; Adoption of new technologies; Relationship with the client and other subcontractors; Timely Completion [25];
- Timely completion; Planning; Management / Leadership level; Profits; Cash flow; Profit growth; Relationship with the client and other subcontractors; Team spirit; Team qualifications [26].

These works show criteria related to previous experience or performance, criteria related to performance or financial capacity, criteria related to communication or relationship with other parties involved in the project. It is also noted that some criteria are related to occupational safety, environmental

protection, and availability of resources. According to [26], different criteria should be defined for different groups of subcontractors since they perform specialized work and differ from each other.

In the literature, there are proposals of methods for assigning classifications, to make their assignment methodical, thorough and complete, thus avoiding uncertainty and different classifications between moments [20, 27]. Ng & Skitmore [28] propose the use of the BSC tool to evaluate subcontractors' performance against predefined objectives and [29] suggest the application of a registration system that uses artificial intelligence, whose result is the evaluation of the subcontractor's profile and for which work is approved.

2.2. Supplier pre-qualification in the construction industry: criteria and methods

The pre-qualification in the CI suppliers' literature is unexplored, except for the work of [30] where criteria for supplier evaluation for the CI are investigated. The authors define the following evaluation criteria: Quality, whose sub-criteria are process quality and product quality; Cost, whose sub-criteria are the purchase price, shipping value, and payment condition; Relationship history; and Delivery time, whose sub-criteria are delivery flexibility, cooperation history, and capacity. To assign the classification, the authors use a complex automatic system using fuzzy logic.

2.3. Research gap

Through the literature review, it is possible to infer that a pre-qualification stage is a form of control that minimizes the risk by delegating the work to a subcontractor or ordering the material/equipment from suppliers. Firstly, the literature is little explored for the pre-qualification stage. However, it is clear from existing work that all (except for [27]), distinguishes suppliers from subcontractors. They use performance evaluation criteria and, finally, the methods suggested in the literature, besides being scarce, are complex and intend to deal with, or diminish, the impact of human subjectivity when assigning a classification to obtain an exempt classification.

The manufacturing literature is widely explored for articles on specific criteria for particular conditions, such as criteria for selecting the best supplier for SCM, or criteria for selecting the best green supplier. In the CI, concepts such as Building Information Modeling or Geographic Information System have emerged [31]. It is expected that the path for future studies may be to study criteria for these approaches, contributing to the work of [27].

3. Research methodology

The methodology used in this research was a unique case study in an organization whose complaints focused largely on suppliers (almost 90%) over a longitudinal time horizon with a contact time of 6 months. It used triangulation of sources: observation, consultation of documents and records and interviews with stakeholders in the processes studied.

This study followed the following steps: (a) literature review on the procurement process and supplier selection process and literature review on the pre-qualification stage specifically in the CI; (b) study of the organization's procurement and supplier selection process; and (c) development of pre-qualification method for suppliers and subcontractors (definition of supply chain manager preferences and quality regarding method configuration and specifications; collection of the criteria and sub-criteria of the literature and those existing in the organization; and definition of criteria, sub-criteria and its weights through the Delphi method) [32, 33].

The case study was conducted in an organization that operates under Engineering Procurement Construction (EPC) projects in metal construction for the Oil & Gas sector. It has been present in the market for nine years, and in the last six years, there has been a marked increase in its turnover, the number of employees and the number of projects. This organization is certified by ISO 9001 and ISO 14001.

4. Problem description and suppliers' pre-qualification method requirements

The results found when studying the procurement and selection processes of suppliers were as follows:

- The organization has a defined procurement process. In this process there is the procedure for monitoring the performance of suppliers through the weighted result method, for which the same criteria and weights are defined for all types of supply. This assessment is done every six months and uses the experience of supply chain and quality managers (who have little contact with suppliers);
- Regarding the criteria mentioned above, they are process evaluation criteria. Although the defined criteria match the literature on financial capacity, environmental management, occupational health and safety management, technical capacity, the criterion defined as quality does not seem to measure the ability to provide quality product/service, evidencing difficulty defining quality in the CI;
- There is no supplier selection process defined. So, there is full autonomy by the decision-makers, resulting in different preferences (criteria and weights) in each purchase situation;
- In the processes and procedures studied there is no distinction between suppliers and subcontractors and there is no clear division of types of supplies;
- Supply chain managers and quality managers are unfamiliar with management and improvement techniques.

Analysis of the collected data from the organization's processes shows that there is no prior control of suppliers. They are only controlled after work or supply. Their selection process is not defined, so the selection preferences (criteria and weights) are inaccurate and different in each situation, which imposes uncertainty and ambiguity in selecting the most appropriate supplier. The monitoring method does not

distinguish between the various types of supply, using the same criteria and weights for all supply types and is calculated by two managers with little contact with suppliers. This implies that the results may not correspond to the quality of the service provided or material provided. Not only because they are evaluated against the same criteria (which may not be reasonable) but mainly because evaluations are assigned by those who do not contact the work of the supplier/subcontractor. Thus, the highlighted needs of the organization to improve its supplier control and the preferences of its supply chain and quality managers are shown in Table 1.

Table 1. Organizational needs and managers' preferences.

Organizational needs	Preferences of the supply chain manager	Preferences of the quality manager
Supply Base Initial Filter	Not eliminatory	Short
Adaptable to each type of supply	Quick to get rating	One questionnaire for all supplies
Systematic assessment/classification		

5. Development of the supplier pre-qualification method

The proposed pre-qualification method consists of two separate components: the questionnaire (where the questions correspond to the sub criteria who evaluate the criterion) and the evaluation spreadsheet, which includes the scoring methods for the answers and the scoring methods for the criteria, as well as the method of aggregating the sum and assigning its classification.

5.1. Pre-qualification questionnaire

The pre-qualification questionnaire consists of grouped questions. Each group of questions is associated with the evaluation of a criterion and as such each question corresponds to a sub criterion (see Table 2). As shown in Table 2, the questionnaire only allows direct answers (yes, no, not applicable) or quantitative answers. Thus, it is expected to decrease the ambiguity or uncertainty associated with the responses of different respondents.

The questionnaire was defined for specific supply groups (both suppliers and subcontractors), which must be identified by the supplier / subcontractor at the beginning of the questionnaire, as shown in Fig. 1.

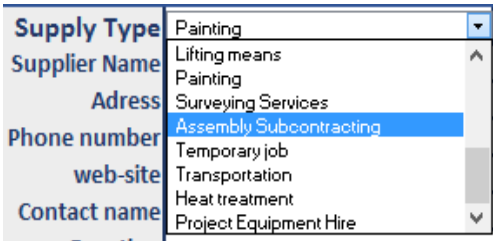

Fig. 1. Supply Type Selection Option.

Table 2. Acceptable questionnaire answers.

Criteria	Sub-criteria	Answer type	Answer option
Quality	EN ISO 9001	Binary	Yes; No
Environment	EN ISO 14001	Binary	Yes; No
Safety	EN ISO 45001	Binary	Yes; No
	Loss ratio	Number sequence	Free
Business capacity	Billing Volume>X?	Number sequence	Free
	Number of Employees>Y?	Number sequence	Free
Technical capacity	EN 1090	Triple	Yes; No; Not applicable
	Drawing software	Binary	Yes; No
	MC experience	Binary	Yes; No
	WC Experience	Binary	Yes; No
	Number of welders available	Numerical	Free
	EN1090	Binary	Yes; No
	Drilling process validation	Binary	Yes; No
	Welders Qualification	Binary	Yes; No
	Welding Equipment Verification	Binary	Yes; No
	Welding Engineer Qualification	Binary	Yes; No

5.2. Classification calculation

The rating is automatically calculated based on the questionnaire responses. The spreadsheet is set to evaluate the typologies presented in Fig. 1 in a customized way. Although the questionnaire is the same, the spreadsheet only considers the predefined criteria for each typology, as well as considers different weights depending on the typology. Figure 2 shows the result presented in the spreadsheet. In the case of assembly subcontracting, the result indicates whether the respondent is fit for both tasks or just one.

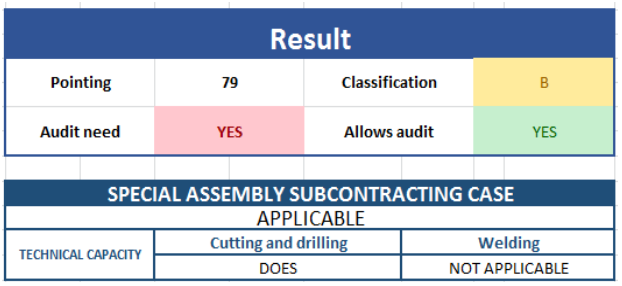

Fig. 2. Results presentation.

The result calculation is performed in two steps: (i) calculating the partial evaluation of the sub-criteria (this is independent of the type of supply) and (ii) evaluating the criteria, which is characteristic of each typology. The sub-criteria classification is defined in Table 3.

After assigning scores to the questions, these partial results, are multiplied by its weight. By default, sub-criteria have the same weight within the criterion. Criteria evaluation is done by summing the values of each sub-criterion multiplied by the criterion weight, which is zero when the supplier is not supposed to evaluate those criteria, and a number between

[0.01; 1] depending on the criterion weight. The final score from the vendor is then converted into rank. The rating scale is presented in Table 4.

Table 3. Sub-criteria classification.

Answer type	Answer option	Score (points)
Binary	Yes	100
	No	0
Number Sequence (A, B, C)	Rising goal	A<B<C: 100; A=B<C: 75; A<B=C: 75; A>B<C: 50; A<B>C:50; A=B>C:25; A>B=C: 25; A>B>C:0
	Descending goal	A>B>C: 100; A>B=C: 75; A=B>C: 75; A<B>C: 50; A>B<C: 50; A<B=C: 25; A=B<C: 25; A<B<C:100
Triple	Yes/Not applicable	100
	No	0
Numerical	Free	>4: 100; 4: 75; 3: 50; 2:25; ≤1: 0

Table 4. Classification scale.

Score	Classification	Result
>79	A	No audit required
[60, 79]	B	Need audit
<60	C	Need audit

The purpose of the rating is to present a "confidence level" conferred by the supplier / subcontractor to the buyer. In this sense, the supplier eligible to be contracted is the one whose classification obtained is A. Suppliers rated B and C to qualify must be audited by the purchasing company. However, as this implies additional expenses with the supplier / subcontractor it is a situation to consider only in case there is no better rated option. There is also division B and C because option B is closer to being fit than an option rated C and if only those two options are chosen then B.

5.3. Advantages and limitations of the proposed method

This evaluation method is fast, versatile, and systematic, using different criteria according to the type of supply. Criteria and weights can be changed. Limitations include relying on external certification assessment, not assigning the size of the task that the supplier/subcontractor is able to perform, so it is expected that smaller suppliers/subcontractors without certification will not be able to obtain “rating A” without auditing, and the method only assesses the technical capacity of three supply typologies, thus assuming that other typologies are not critical to interfere with the project success.

6. Conclusions

It is concluded that the literature on supplier selection, especially about the pre-qualification stage in the CI is little explored. The case study suggests that, contrary to what was expected in the literature, this organization does not distinguish suppliers from subcontractors and prefers to use process evaluation criteria over performance evaluation criteria. As in the study by [3], this case study found difficulty in defining “quality” in the CI. Also, confirming the conclusions of [11] and [12], this Portuguese construction organization is unfamiliar with some management techniques. Thus, the proposed method uses a simple and easy-to-change system to respond to rapid industry changes, rather than the methods proposed in the literature that adopt more complex systems. Therefore, it can be concluded that for this organization with an immature management system, the best supplier control improvement is one that uses a simple but systematic method, so that managers can be involved and thus update the proposed supplier control method.

This study was based on a single case study over a contact period of approximately six months and may, therefore, not be representative of the Portuguese CI. As future work, it is suggested the application of this method to other CI organizations to ascertain the proposed method general applicability.

Acknowledgements

This work has been supported by FCT – Fundação para a Ciência e Tecnologia within the R&D Units Project Scope: UIDB/00319/2020.

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