Instrument for selecting and evaluating suppliers in small and medium-sized metalworking enterprises in Cartagena, Colombia

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Abstract. The objective of this investigation is the definition of a practical tool that helps to improve the selection process and evaluation of suppliers in small and medium-sized metalworking enterprises in Cartagena city. For this purpose, a mixed approach methodology was used where data from 30 projects in the sector were mixed, together with related literature, to identify the most relevant factors. Once the information was reviewed, the multicriteria decision method known as the analytic hierarchy process was applied, where the experience, organizational structure, project resources, technical capacity, and previous performance were used as decision-making elements for the processes related to the selection and supplier's evaluation.

1. Introduction

The building sector on the Colombian Caribbean coast is considered of great importance for the region, as it stimulates investment in infrastructure, generates employment and promotes contracting of numerous goods and services that are part of the value chain of this industry [1]. Concerning this, companies metallurgical are required to offer high-quality products to meet their customers' needs.

In the department of Bolívar, specifically in Cartagena city, strategies have been developed aimed at stimulating innovation in technologies, infrastructure, and operations management, which has allowed an increase in offers and portfolios of services available in the market; however, this multiplicity of options forces to improve supplier selection and evaluation processes in order to establish alliances with entities that really add value to the quality of the final product of metalworking companies [2].

According to the European Social Fund of the European Union, the metalworking industry is cataloged in 3 types: heavy industry, construction and metal projects, and maintenance and repair (Figure 1). Taking into account the above, the second subsector is subdivided into transformation of structural metal products, such as metal structures for rail and maritime transport; steel pipe, non-ferrous metals and plastic; boiler making; manufacture of finished articles, such as metal objects by punching and embossing; or surface treatment and coating of metals through electrodeposition chemical procedures [3].

As shown in Figure 1, there is a great diversity of types of companies in the metal-mechanic industry of Cartagena city; however, those directly related to construction, which make up the second subsector, are the ones in which this research is carried out.

In Cartagena City, according to figures from "Cámara Fedemetal", the largest number of metal-mechanic companies are engaged in the production of metal-made elements [4]. On the other hand, most

of the organizations in this industry are micro-companies, represented by 93.3% of the companies focused on metal-mechanic manufacturing, which contribute with an 81% employment generation of the industry; additionally, it is found that 80.85% of small and medium-sized enterprises (SMEs) are oriented to industrial maintenance, with a 50% employment generation of the total [5]. The above information shows the importance of the industry in the region, hence the need for these organizations to implement mechanisms to increase their competitiveness and actively contribute to improving the market in the value chain to which they belong.
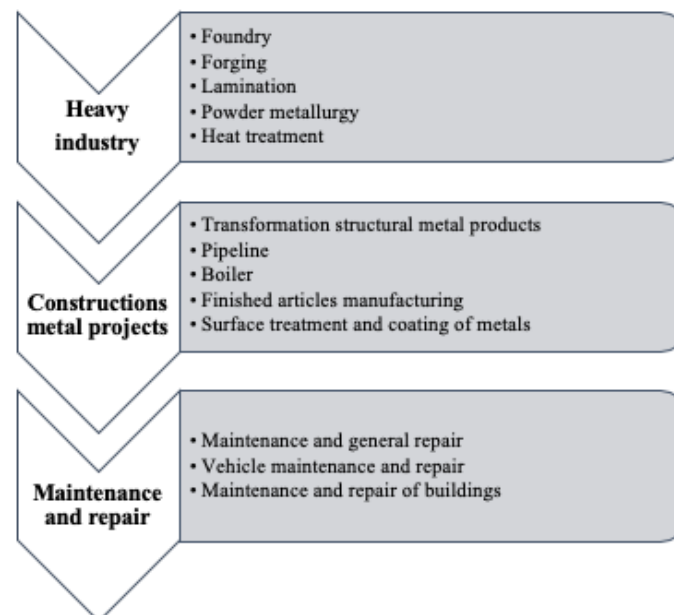

Figure 1. Components of the metalworking industry in Cartagena.

Generally, the projects highlight three essential factors for achieving success, such as the schedule, cost, and quality, so that the performance in each of the three aspects impacts on the satisfaction of the requirements raised. However, considering the previous figures, related to the type of companies in the sector, it is possible to establish the importance of productive linkages, so that by associating they make it possible to overcome gaps at a competitive and productive level, time that better learning processes are generated and the complementarity between the different organizations is exploited.

Therefore, it seeks to establish a reliable method of selection and evaluation of suppliers, which allows metal-mechanic companies to integrate adequately into projects from other industries, through the achievement of goods and services with quality standards required in the current economic environment.

2. Methodology

For this research development, a mixed approach was used where quantitative information was analyzed based on the review of practices, tools, and mechanisms used by SMEs in the metal-mechanic industry; to determine the critical factors in the processes of selection and evaluation of suppliers [6]. On the other hand, a qualitative approach was used to assess the opinion of experts in the area of contracting suppliers of companies in the sector, which was useful to identify the success factors of these processes [7].

Thus, a descriptive/proactive type research with a non-experimental design is proposed, which seeks to expose the characteristics, components and other elements that characterize the processes of contracting suppliers, to interpret their behavior and thus make a proposal that facilitates the achievement of the objective without intervening in the variables that make up the phenomenon and in this way avoid any type of manipulation that could affect the results [8].

For the proposed analysis, it was inquired about the aspects considered important in the hiring processes used by SMEs, to achieve a current diagnosis of this type of activity, considering the related information of 4.605 metalworking SMEs in the city of Cartagena [9]. Likewise, 30 projects were analyzed from a purposive non-probabilistic sample of 8 SMEs, where their managers or project leaders were surveyed to obtain their perception of the most relevant aspects of their performance [10].

As an instrument for gathering information, a standardized survey of closed questions was designed, based on the studies of Alzahrani and Emsley [11] and the investigations of De Araújo, Alencar and De Miranda [12], which allowed identifying the most relevant concerns for the success of the hiring processes. This survey was composed of three sections, the first one was related to the identification of methodologies, standards or practices used in the hiring processes; the second, in search of typifying the main criteria taken into account in the selection of suppliers; and in the third, the information related to the evaluation of the contractors was analyzed. Subsequently, the information collected was analyzed through the use of the software SPSS version 24, from which the data were tabulated and the descriptive analysis of the information was made through tables of percentages and graphs, concerning the type of variables observed.

Now, once the information has been analyzed, the multicriteria decision methods (MCDM) were applied to structure a solution that would allow all the variables identified to be considered, while at the same time taking into account the way they impact on the results [13]. For the above, the MCDM requires two aspects: the identification of key criteria and their respective sub-criteria; at the same time that an in-depth evaluation is made on the relevance and weighting of each one of them. Taking into account the above, Roy and Słowiński [14] made a compendium of the most used MCDM methods in the solution of highly complex problems (Table 1). The options are varied, so those tools must be analyzed according to the context in which they are intended to apply, since some of them offer a better solution alternative but its application is more expensive, while others are more versatile and simpler, however, the results obtained are less accurate [15].

Table 1. MCDM classification.

Focus	Acronym	Method
Based on the theory of value	AHP	Analytic hierarchy process
	ANP	Analytical networks
	COPRAS	Proportional complex evaluation
	TOPSIS	Technique for order of preference by similarity to ideal solution
	UTA	Additive utilities
	MCS	Monte Carlo simulation
	MAUT	Multi-attribute utility theory
	MAVT	Theory of multi-attribute value
Classification methods	PROMETHEE	Preference classification
	ELECTRE	Options elimination
	GRIP	Generalized regression
	RUTA	Preferential disaggregation method

Due to the above, it is possible to establish that one of the most widely used methods, due to its adaptation and ease of implementation, corresponds to AHP, developed by Thomas Saaty [16], and which is composed of the following key elements:

    a) The representation of the problem in criteria, sub-criteria, and alternatives to a possible solution.
    b) The weighting of the elements on which a decision must be made.
    c) The importance evaluation by defining values or weights to the identified criteria.
    d) The ordering and selection of the best alternatives.
    e) Carrying out a sensitivity analysis to determine the validity of the results.

In relation to these components, the AHP method has the purpose of decomposing a problem according to its problems and specific criteria for the selection of an appropriate solution, for which it is essential to follow a logical sequence of analysis as well as the appropriate definition of the objectives of the intended solution, as shown in Figure 2.
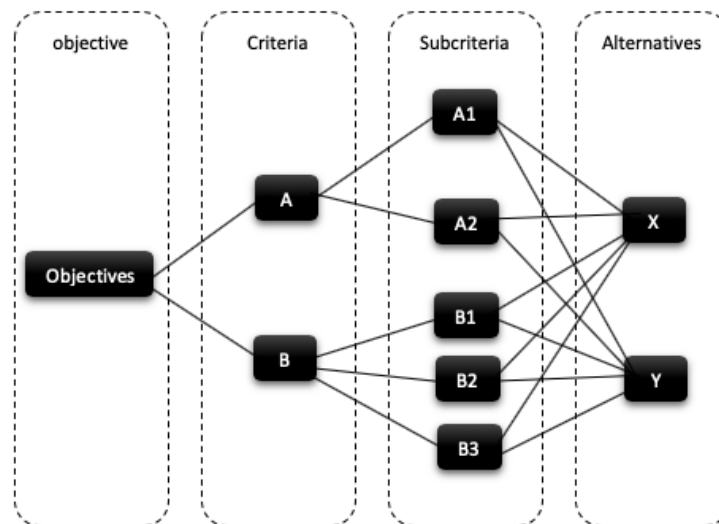

Figure 2. AHP process.

As seen in Figure 2, the AHP method is based on the comparison of ordered pairs in relation to their order of importance or probability of occurrence; this assessment is determined from a scale developed by Saaty himself [16], which allows assigning scores according to the judgment of the expert; in this way, such ratings are determined according to the weightings that the decision-maker assigns to each set of elements evaluated. However, the scale proposed by Saaty [16] prescribes some criteria of importance and gives odd values to those of an absolute nature, and pairs to the intermediate criteria, as shown in Table 2.

Table 2. Saaty scale [16].

Numerical scale	Verbal scale
1	Both criteria are of equal importance
3	Weak importance of one over another
5	Strong importance of one criterion over another
7	Demonstrated importance of one criterion over another
9	Absolute importance of one criterion over another
2,4,6,8	Intermediate values that are used to define middle terms
2	Equally and moderately preferable
4	Moderately and strongly preferable
6	Strongly and extremely preferable
8	Very strongly and extremely preferable

3. Results and discussion

From the information gathered it was possible to identify the critical variables for the selection and evaluation of suppliers. Initially, the instrument used to collect the data was validated using the Cronbach's Alpha, which resulted in $\alpha = 0.792$, for the 19 items in the Likert scale corresponding to sections 2 and 3; this is how, once its validity was verified, it was observed that, of the 30 projects evaluated, 10 were in execution, while the remaining 20 had been completed.

From the projects analyzed, it was identified that all of them took care of the good use of the methodologies, standards and good practices related to procurement management; at the same time,

methods and tools for the selection and evaluation of suppliers were taken into consideration, clearly defining the criteria for contracting and monitoring them. Nevertheless, deficiencies were observed in the final quality of the manufactured product as a consequence of lack of adjustment between the requirements and the goods and services contracted; in addition to inefficiencies in the audit processes that allow the timely and adequate evaluation of the procurement management of the projects considered.

It is consistent with the thesis of Alzahrani and Emsley [11] concerning the importance of an adequate evaluation of suppliers since it is considered that they bear a large part of the responsibility for providing the necessary elements to guarantee a product or service of quality, according with the requirements. With this, it is observed that there are still opportunities for improvement where measures can be implemented to improve organizational performance, and therefore achieve a reduction in costs, time and an increase in the quality of the final result. Then, the concordance of the positions of the leaders was evaluated through the statistical method W of Kendall, whose result was 0.764 which is in the range between 0 and 1, which ensures a high degree of agreement between the opinions [17].

Based on the results, it is highlighted that among the criteria most used for the selection of suppliers is the recognition of a positive experience in previous projects (90%), the technical and management capacity (90%), the availability of the resources needed (100%), have an organizational structure that supports operations (100%) and finally have extensive experience in the project sector (100%). However, it was observed that in a large part of the cases analyzed, it was not considered relevant to incorporate measures that comply with safety regulations in the activities used for the contracted supply.

The findings regarding the suppliers selection are consistent with the approaches of Shafahi and Haghani [18], who establish that the positive experience prior to hiring contributes to significantly increase the overall profitability of the project; additionally, the inclusion of logistical, technical and organizational capacities are considered critical insofar as they minimize the negative impact resulting from not having the necessary skills and abilities in the contract [19]. The Kendall W concordance index of these opinions analyzed was 0.251, which is closer to 0 which indicates that there is little homogeneity in the results, that is, high diversity in the definition of critical variables in the process.

Once the critical factors that determine the selection of suppliers have been defined, the valuation of suppliers should be continued according to the selected criteria, and according to the level of compliance or development found in each one of the bidders. In this sense, each one of the criteria must be defined in sub-criteria and assigned a score in such a way that it results in an assessment concerning the adjustment of the characteristics of the provider with the requirements of the company or project. The above must be done through rating scales, as presented in Table 3.

The selection of suppliers is only the initial phase of a process of building alliances in shaping the industry's value chain; in such a way that this stage is provided to achieve a supply of goods and services that are closer to the needs of the project. However, the relationship with suppliers is just beginning and therefore periodic evaluations should be carried out to assess the products received, and determine the level of satisfaction while contributing to the identification of aspects susceptible to improvement.

Now, based on the results of the research conducted with SMEs in the sector, the most relevant factors were identified to determine the continuity of the suppliers, which in order of importance, turn out to be:

- Compliance times and lapses
- The efficiency of the organizational structure
- Use of resources for the achievement of objectives
- Budget adjustments based on costs
- Overall project performance
- Demonstration of technical and logistic capabilities
- Compliance with customer requirements
- Adequate management of environmental aspects

Once the main criteria have been identified, an assessment of the contractor's performance concerning each of them is obtained; for this, a rating scale of 1 to 5 is used, where 1 is very low and 5 is very high. This score is combined with a weighting of the evaluation factors, which is intended to achieve a final assessment; an example of this is presented in Table 4.

If the case were that of a supplier with a rating of 3.5, this indicates that this company must develop measures to close the service gap, since this score reveals weaknesses that must be worked to bring the supplier even closer to the project needs. According to the importance of this stage of the process, it is recommended to develop the evaluation of suppliers in periods of 6 to 12 months, or once the supply is completed, in such a way that the aspects that should be improved can be observed in time.

Table 3. Evaluation of criteria for the selection of suppliers.

Criteria	Sub criteria	Category	Score
Experience in the sector	• Years of experience in the sector • Years of experience executing specific activities required for the project	Less than one year	1
		Between 1 and 3 years	2
		Between 3 and 5 years	3
		Between 5 and 10 years	4
		More than 10 years	5
		NA, doesn't know	0
Organizational structure	• Customer service cannel • Clear administrative and accounting processes • Support logistic structure	Very low	1
		Low	2
		Medium	3
		High	4
		Very high	5
		NA, doesn't know	0
Resources to execute the Project (economic, human and logistic)	• Have the economic resources to execute the contracted project • The organization has the human capital to execute the project • It has enough logistic resources to execute the contracted project	Very low	1
		Low	2
		Medium	3
		High	4
		Very high	5
		NA, doesn't know	0
Technical capacity	• Quality and detail of the technical offer to execute the project is: • Communications of technical and operational capacities of the personnel executing the project • The Project management mechanisms of this Company are:	Very low	1
		Low	2
		Medium	3
		High	4
		Very high	5
		NA, doesn't know	0
Performance in previous projects.	• Qualification and/or recommendation of performance in previous projects • Reputation in the sector	Very low	1
		Low	2
		Medium	3
		High	4
		Very high	5
		NA, doesn't know	0

Table 4. Example of supplier evaluation.

Criteria	Weighing	Assessment	Total score
Criteria 1	40%	4	1.6
Criteria 2	30%	4	1.2
Criteria 3	10%	3	0.3
Criteria 4	20%	2	0.4
Total	100%	13	3.5

It should be noted that, in order to obtain comparable results, the evaluation of suppliers must be carried out with the same methodology, regardless of the analyzed period, in such a way that it is possible to validate the new tool not only based on the satisfaction of the results of new hires but also from the incremental improvement that this new methodology can bring to the purchasing and procurement processes. By virtue of the results it is possible to establish the new methodology as a tool to select a diverse set of suppliers for each type of project, in such a way that the AHP method allows adjustments to be made consistent with the context of the project analysis; In this way, the feedback of the selection process is considered fundamental to introduce measures that contribute to the continuous improvement of the processes.

4. Conclusions

The development of the research contributed to the identification of the main assessment criteria that the managers of metalworking SMEs in Cartagena consider for the selection and evaluation of suppliers. In the preliminary result**s,** it was found that the majority of SMEs have standardized hiring processes, however, there are still shortcomings in the monitoring or determination of the effectiveness of the processes carried out. On the other hand, two types of selection criteria were obtained, from which the experience, the organizational structure, the technical capacity and the performance in similar projects could be collected as fundamental; even so, it can be said that the importance assessment depends on the type of project or organization. Around the evaluation of suppliers, the managers of the SME metalworking projects were of the opinion that the most relevant aspects were represented by the fulfilment of the times established for the delivery of the good or service, the organizational structure prepared to respond to the requirements of the project, the administration of resources, as well as respect for environmental regulations and budgetary adjustments in relation to costs. On the other hand, with the information collected, a multicriteria model was constructed based on the guidelines of the AHP method, from which the factors and useful valuation scales were established to provide a selection criterion to ensure satisfaction of the project requirements. Such methodology covers not only the selection but also the processes for the evaluation of the suppliers.

References

[1]   Departamento Administrativo Nacional de Estadística (DANE) 2015 *Informe de coyuntura económica regional – departamento de Bolívar* (Bogotá: Departamento Administrativo Nacional de Estadística)

[2]   J E G Díaz, Á A Á Sampayo 2018 Determinantes del crecimiento empresarial de las mipymes metalmecánicas de Cartagena (2004-2010) *Visión Empres.* **4** 80

[3]   Fondo Social Europeo (FSE) 1997 *El sector metal-mecánico en Cartagena - Perspectivas del sector y necesidades formativas* (Madrid: Fundación EOI)

[4]   Asociación Nacional de Industriales (ANDI) 2011 *La cadena de valor siderúrgica y metalmecánica en Colombia, en la primera década del siglo XXI* (Cartagena: Asociación Nacional de Industriales y Cámara Fedemetal)

[5]   Cámara de Comercio de Cartagena 2010 *Resultados del censo económico de Cartagena* (Cartagena: Cámara de Comercio de Cartagena)

[6]   G Polat and E Eray 2015 An integrated approach using AHP-ER to supplier selection in railway projects *Procedia Eng.* **123** 415

[7]   C A Ramos 2015 Los paradigmas de la investigación científica *Av. En Psicol.* **23(1)** 9

[8]   P M Nardi 2018 *Doing survey research: A guide to quantitative methods* (United State of America: Routledge)

[9]   R W Emerson 2015 Convenience sampling, random sampling, and snowball sampling: how does sampling affect the validity of research *J. Vis. Impair. Blind.* **109(2)** 164

[10]   Centro de Estudios para el Desarrollo y la Competitividad 2019 *Informe económico de los municipios de la jurisdicción de la Cámara de Comercio de Cartagena 2018* (Cartagena: Cámara de Comercio de Cartagena)

[11]   J I Alzahrani and M W Emsley 2013 The impact of contractors' attributes on construction project success: A post construction evaluation *Int. J. Proj. Manag.* **31(2)** 313

[12]   M C B De Araújo, L H Alencar and C M de Miranda Mota 2017 Project procurement management: A structured literature review *Int. J. Proj. Manag* **35(3)** 353

[13]   M Velasques and P Hester 2013 An analysis of multi-criteria decision-making methods *Int. J. Oper. Res.* **10(2)** 56

[14]   B Roy and R Slowiński 2013 Questions guiding the choice of a multicriteria decision aiding method *Euro J. Decis. Process* **1(1-2)** 69

[15]   K Govindan, S Rajendran, J Sarkis and P Murugesan 2015 Multi criteria decision making approaches for green supplier evaluation and selection: a literature review *J. Clean. Prod.* **98** 66

[16]   T L Saaty 1990 How to make a decision: the analytic hierarchy process *Eur. J. Oper. Res.* **48(1)** 9

[17]   M G Kendall and B B Smith 1939 The problem of m rankings *Ann. Math. Stat.* **10(3)** 275

[18]   A Shafahi and A Haghani 2014 Modeling contractors' project selection and markup decisions influenced by eminence *Int. J. Proj. Manag.* **32(8)** 1481

[19]   H Abbasianjahromi, H Rajaie and E Shakeri 2013 A framework for subcontractor selection in the construction industry *J. Civ. Eng. Manag.* **19(2)** 158