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Evolving Trends of Selection Criteria for Industrial Suppliers

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Abstract — The industrial company needs innovation to remain competitive in the global economy. Successful introduction of new products is important to the company survival. However, in the context of partnership and subcontracting, this capacity almost always depends on the performance of suppliers whose contributions to the project can influence both the industrial strategy of the company and the product architecture. In this case, the selection of industrial suppliers must be taken into consideration to minimize any industrial risks. These conditions will have a direct impact and consequences on the technical and technological characteristics of the product, as well as on the duration and overall cost of it. Our work initially illustrates a selection methodology for industrial suppliers. Based on a survey done on more than 50 international companies, we identify the rank of the most used criteria. Then, by using a statistical technique on MATLAB 2019 (Friedman's analysis), we list the most important criteria for selecting an industrial supplier in 2020.

Keywords **—** Network of industrial supplier, selection methodology of industrial supplier, supplier selection criteria, decision making

I. INTRODUCTION

The launch of complex products in the market (products + related services) is an important strategic challenge for companies. The capabilities that companies need to develop not only concern technological innovation but also fall within the internal and external organizational domains, or even partnership activities. It is necessary to study the technical and organizational feasibility of innovation with regarding all these constraints and in particular those related to the operating modes of the network of industrial suppliers that are defined or to be built. The best choice of an industrial supplier for products and services is a critical decision for many companies. Therefore, managing industrial supplier participation in product design and development can be considered as a crucial and strategic process.

The major problems for companies during their product development activities can vary from the lack of capacity of the company, the lack of technology that can ensure the development of a product, the lack of knowledge, the lack of sufficient information, etc... For these reasons, companies are required to collaborate with other companies (suppliers, sub-contractors, research and development centers, etc.). In our work, we focus on the selection of industrial suppliers.

The other issues that arise, therefore, are the criteria, the methods, the procedures and selection methodology of these industrial suppliers. The best choice has the advantage of positioning the company ahead of potential partners in a negotiation strategy.

Researchers began to study this problem since the sixties. They have defined selection criteria libraries, without giving them an order of preference, thus making it possible to adapt the selection approach to particular situations. A few years later, the methods of selecting industrial suppliers, or partners in general, and the prioritization of criteria appeared to allow for a more relevant choice of partners.

The work proposed in this paper consists of initially presenting a detailed bibliographic study on the collaboration, the selection criteria of industrial suppliers, or partners in general. For Wehbe (2011), the cost of the project is directly related to the number of used criteria [1]. If the number of criteria is reduced, the cost of the project is minim. For this reason, our main objective is to reduce the number of used criteria to select the best supplier.

This paper is organized as follows: Section I contains the introduction of our context research; section II explains the selection methodology of industrial supplier; section III presents the literature review concerning the supplier selection and shows partnership and collaboration issues as well as the criteria for selecting industrial suppliers; section IV contains a study about the criteria used in 2020; section V describes the results of the data analysis. Section VI contains the discussion and recommendations about the result of our study and section VII concludes the research work and presents the perspectives of this study.

II. SELECTION METHODOLOGIES OF INDUSTRIAL SUPPLIERS

In our research work, we find different studies concerning the selection methodologies of industrial suppliers. Li et al., propose, in 2018, innovatively to add semantic assistance into the supplier selection process wherein a two-phase negotiation algorithm is suggested [2].

For Ayhan and SelcukKilic, the process of selecting the partners is the basic step to find the best entity (industrial partner, supplier...) to obtain the articles according to various criteria. Consequently, this selection is an important decision to study [3].

In 2016, Garg presents a study concerning the evaluation and the selection of the strategic alliance partner in the airline industry. The author presents a model-based approach of an Analytic Hierarchy Process (AHP) for the evaluation of criteria and the selection of strategic alliance between partners [4].

Alfaresa and Turnadi [5] present a general model for a realistic multi-item lot-sizing problem with multiple suppliers, multiple periods, quantity discounts, and back ordering of shortages. For the authors, due to the large number of variables and constraints, the model is complicated to be solved optimally for practical cases. For this reason, they propose two heuristic solution methods. This case is similar to our case study concerning our multi-type and number of criteria.

Wehbe [1] conducted a detailed study on the choice of partner selection criteria. He developed a mathematical model to reduce the number of using criteria without influencing the classification of the partners or suppliers.

In our study, we consider that the choice of industrial suppliers requires a clear and standard methodology. For this reason, we propose a selection methodology applied by the 'decision-makers' i.e. the industrial managers of the main company, and we describe it in Figure 1.

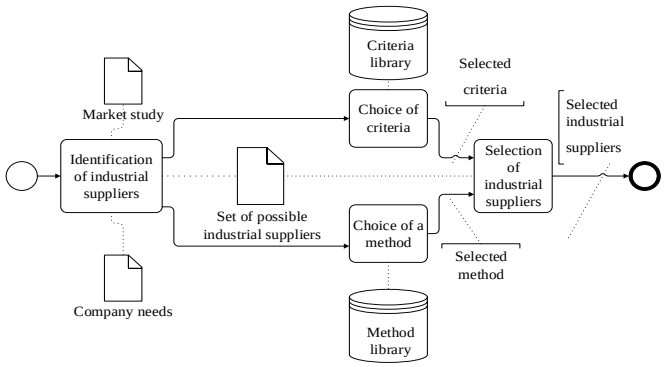

Figure 1 Selection Methodology of Industrial suppliers

For any selection of industrial suppliers, decision makers need a selection criteria library, a selection method library, and a set of potential industrial suppliers. These decision makers receive a market study and the internal needs of their company so that they can identify on the one hand the best selection method and on the other hand the fundamental criteria for this selection. Once the criteria and the method have been selected, the decision maker can select the best industrial suppliers. In the next section we will focus on the 'choice of criteria' activity and establish a state of the literature in order to choose a set of criteria.

III. LITERATURE REVIEW

The question of supplier or partner selection is understood as a challenge to find the best choice. The selection of industrial supplier is not always easy. To facilitate this choice, this state-of-the-art analysis is focused on supplier and partner selection as it is addressed by academic research and industrial practices.

The essential idea of this research is that, from the very beginning of the extended product design project, the company must manage all its design activities. The mastery of the multi-dimensional design should ensure the profitability of the extended product for the company in the short and medium terms.

It is then necessary to study the feasibility of innovation regarding all these constraints and in particular those related to the operating modes of the network of suppliers, that are defined or to be built.

Many of the works deal with problems related to the reasons for choosing the suppliers of the company, whose goal is always to stay in a win-win strategy.

Highlighting cooperation skills around product design/ development activities reveals the role played by the creation of a collective intelligence within companies.

A. Partnership and collaboration issues

Many studies have attempted to pinpoint the problems of the partnership between different actors in the industrial sector.

Lewis [6] presents the importance of collaboration between General Electric and France's SNECMA, in the early 1970s, which manufactured jet engines for the Mirage fighter. For the author, General Electric and France's SNECMA formed a joint venture to build a new class of commercial aircraft engines. General Electric had most of the technical skills but could not afford to develop and produce the engines by itself. General Electric had poor access to the growing European commercial market. SNECMA had related technical know-how, good European market contacts, and financial depth, but no commercial experience. Together, both companies had the needed technical, marketing, and financial resources that neither could assemble alone.

In [7], the author considers that companies have two solutions to improve their business performance: better strategic positioning and better operational efficiency. It takes strategic positioning by doing "things different from competitors" and operational efficiency by doing "the same

things as competitors but better", e.g. faster or at a lower cost.

We find in [8] that industrial companies have increasingly recognized the need to decline the objectives in terms of cost, quality and time, from the early stages of design. For the author, the economic analysis of the design activities, has shown that it is during the early design phases that the study of design alternatives is the least expensive. It is therefore during the first phases of the design that it is preferable to build the compromises between the different actors involved in the design. He refers to an international survey conducted by Arthur [9], which identifies the main directions of the efforts of the industrial enterprises concerning the product innovations they implement: "where companies put their efforts in product innovation".

For Croom [10], partner or supplier choice for the goods and services indicated is a critical decision for many purchasing organizations, since supply execution can have a direct financial and operational impact on the business.

In design, choice becomes more important as suppliers are involved in the specification of goods and services; therefore, commitment to a particular source of supply may be included in the product design. Collaboration is defined by Lambert et al., as a relationship of partnership built on mutual trust, profit-sharing, and risk. Its main objective is to provide a competitive advantage, the result of a combined performance of the players [11].

For Da Silveira and Cagliano, collaboration involves better coordination, joint decision-making and the creation of many standards among partners, aspiring to increase the use of resources and increase the value added to the product and services [12].

Zolghadri et al., explain the issue of co-design [13]. The authors say that it is: "more difficult to run for small and medium enterprises than for large groups, mainly because of the very harsh constraints on their limited technical, human and financial resources". As a result, SMEs need to collaborate with associates. The authors distinguish two categories of partners in the context of co-design: 1) Critical associates, who directly influence the technical, technological and functional aspects of the products; 2) support associates, who have no direct influence on product design. The collaborative project is divided into three main phases: analysis, design and production. The authors divide the design phase into four design processes that work in parallel: **S**ervices associated with the product, the **P**roduct itself, the **I**nternal facilities and processes, and finally the **N**etwork of partners. The authors therefore call this model, the SPIN model - “S” for “Service”, “P” for “Product”, “I” for “Internal” and “N” for “Network” [13].

Liang and Mei examine in 2019 the following research question in partner selection decisions in business-to-business strategic partnerships/collaborations literature: “How do inertia and uncertainty affect partner selection?”. This research analyzes how inertia of previous alliance selection routines and uncertainty of entire market movement shapes firms’ preferences regarding exploratory partner selection, for example selecting a new supplier who never collaborates with the focal company [14].

Shevtshenko et al., prove, in 2019, that appropriate partner selection is a vital success factor in any collaboration. For the authors, existing collaborative networks such as conventional supply chains spend considerable time and money searching for suitable partners [15].

For Wehbe et al., product design projects performance depends on the ability to coordinate and control the collaboration between the numerous participating stakeholders: e.g. designers, experts from different disciplines and with different experiences, and external partners [16].

As a result, such studies lead to the identification of several issues that foster or penalize the quality of the collaboration between a company and its suppliers. In the next section we analyze the criteria that can help a company to manage such issues and to select a relevant supplier.

B. Criteria for selecting industrial suppliers

The methods and criteria for selecting suppliers are closely linked. We have, therefore, carried out a bibliographic study concerning the criteria, whose objective is to know how they are used, how they were chosen, and which criteria to select for which method. According to the different research we have carried out, we noticed that since the sixties, various studies have been carried out on the definition of the selection criteria of suppliers or partners, so that this selection can be made on the basis of precise and robust criteria. In this section, we present a synthetic study of some research concerning criteria identification. Weber et al. conducted a large study on the criteria for selecting partners, which we synthesize in Table 1.

Table 1: Synthesis based on the study by Weber et al., concerning the selection criteria [17]

Criteria	References
Quality, delivery, net price, reputation and industrial positions, geographic location, reciprocal agreements, technological capability, communication systems, purchasing	[18]
Quality, delivery, net price, technical capacity of the partner, purchases	[19]
Price, quality, geographical location, capacity and ease of production, purchases	[20]
Capacity of production, technological capability, financial position, industrial reputation, internal organization, control operations, repair services, geographical location	[21]
Delivery, purchases and the net price of the product	[22]
Delivery, net price, technical capacity, capacity and ease of production of the partner, purchasing, conceptual capacity of the partner	[23]
Quality, delivery, location, partner attitude, on time delivery, design capability	[24]
Delivery, purchases, net price of the product	[25]
Quality, delivery, partner performance history, capacity and ease of production, net price, technical capacity, compliance with tendering procedures, reputation and position in the industry, management and organization, geographical location, purchasing	[26]
Net price, product purchase process	[27]

We find further studies concerning partner selection criteria, [28], [29], [30], [31], [32].

Supplier selection criteria in a supply chain have been proposed by Shore and Venkatachalam [33]: costs, financial capacity and stability, collaborative potential, production skills, production scheduling.

Benyoucef et al., spoke of an interesting work which is referenced by the majority of papers dealing with supplier or vendor selection problem [34]. This work was presented by Dickson in 1966 [35]. Dickson's study was based on a questionnaire sent to 273 purchasing agent and managers selected from membership list of the National Association of Purchasing Managers. The list included purchasing agents and managers from the United States and Canada. A total of 170 Dickson's studies regarding the importance of 23 criteria for supplier (vendor) selection. Indeed, the 23 criteria are ranked according to their importance observed in the beginning of the sixties. At the time (1966), the most significant criteria were the "quality" of the product, the "one-time delivery", the "performance history" of the supplier and the "warranty policy" used by the supplier.

Criteria used in Dickson' study are:

1. The net price (including discounts and freight charges) offered by each supplier.
2. The ability of each supplier to meet quality specifications consistently
3. The repair service likely to be given by each supplier.
4. The ability of each supplier to meet specified delivery schedules.
5. The geographical location.
6. The financial position and credit rating of each supplier.
7. The production facilities and capacity of each supplier.
8. The amount of past businesses that have been done with each supplier.
9. The technical capability (including research and development facilities) of each supplier.
10. The management and organization of each supplier.
11. The future purchases each supplier will make from your company.
12. The communication system (with information on progress data of orders) of each supplier.
13. The operational controls (including reporting quality control, and inventory control systems) of each supplier.
14. The position in the industry (including production leadership and reputation) of each supplier.
15. The labor relations record of each supplier.
16. The attitude of each supplier toward your organization.
17. The desire for your business shown by each supplier.
18. The warranties and claims policies of each supplier.
19. The ability of each supplier to meet your packaging requirements for his product.
20. The impression made by each supplier in personal contacts with you.
21. The availability for training aids and educational courses in the use of the product of each supplier.
22. Compliance or likelihood of compliance with your procedures (both bidding and operating) by each supplier.
23. The performance history of each supplier.

Other authors present a classification of all the articles published since 1966 (74 articles) according to the criteria treated [17]. They observe that price, delivery, quality, production capacity and location are the criteria most often discussed in the literature.

We find series of criteria concerning the choice of suppliers identified by Dickson [35]. Another set of criteria is carried out by Barbarosoglu and Yazgac in 1997, and these are classified according to several levels [36].

A study of a new model of customer-supplier relationships targets the special interest in their processes for developing new products. This study is presented by Huang et al., in 2003 [30]. This model includes the following four types of distinguishing indexes: Satisfaction Index, Flexibility Index, Risk Index and Confidence Index.

For Noyel et al., the classification approach had been used in order to improve the quality of a lacquering process at an industrial company [37];

Luthra et al., consider three dimensions of criteria: economic, environmental, and social. The authors propose a framework to evaluate sustainable supplier selection by using an integrated Analytical Hierarchy Process (AHP), a multi-criteria optimization and compromise solution approach [38].

Thomas et al., presented a study concerning the impact of the choice of selection criteria on the manufacturing processes [39]. Table 2 lists some other recent studies on selection criteria.

Table 2: Summary of criteria for selecting partners

Criteria	References
Environmental costs, Quality of product, Price of product, Occupational health and safety systems, Environmental competencies	[38]
Quality, time, price, industrial capacity, services, technology management	[32]
Delivery reliability, price competitiveness, service, technological capability	[31]
Costs, financial capacity and stability, collaborative potential, production skills, production scheduling, program quality management, technological infrastructure for information exchange, ability to exchange information, supplier sourcing strategies	[33]

Huang and Keskar have defined, in 2007, 101 criteria for partner selection [40] (see Table 3). The authors ranked these criteria under 7 categories:

1. Reliability: Criteria regarding the performance of a supplier in delivering the ordered components to the right place, at the agreed upon time, in the required condition and packaging, and in the required quantity
2. Responsiveness: Criteria related to the speed at which a supplier provides products to the customer

3. Flexibility: Criteria regarding the agility of a supplier in responding to original equipment manufacturers demand changes
4. Cost and Financial: Criteria regarding cost and financial aspects of procuring from supplier
5. Assets and Infrastructure: Criteria regarding the effectiveness of a supplier in managing assets to support the original equipment manufacturers demand
6. Safety: Criteria regarding occupational safety at the supplier's facility
7. Environment: Criteria regarding a supplier's effort in pursuing environmentally conscious production.

Table 3. 101 criteria for partner selection [40]

	Reliability metrics	52	Discount rate
1	% Orders received damage free	53	Financial stability
2	% Orders received complete	54	Packaging cost
3	% Orders received on time to commit date	55	Inventory carrying cost
4	% Orders received on time to required date	56	Order fulfillment costs
5	% Orders received defect free	57	Freight
6	%Orders received with correct shipping docs	58	Value added productivity
7	% Short to manufacturing schedule	59	Release cost per unit
8	Fill rate	60	Cost reduction trend
9	Ratio of actual to theoretical cycle time	61	Foreign exchange rate fluctuation
10	Scrap expenses	62	Local price control
11	In process failure rate	63	Tariffs and custom duties
12	Yields during manufacturing		**Assets and Infrastructure metrics**
13	% Errors during release of finished product	64	Labor stability
14	Incoming material quality Control	65	Asset turns
15	Inventory accuracy	66	Company size
16	% Faultless installations	67	Quality system certification/ Assessment
17	Order consolidation profile	68	Strategic fit
18	% Orders scheduled to customer request date	69	Negotiability
19	Average days per engineering Change	70	Legal Claims
	Responsiveness metrics		
20	Published delivery cycle time	71	Critical process subcontracting
21	Order fulfillment lead time	72	Inventory days of supply
22	Return product velocity	73	Capacity utilization
23	Average release cycle of changes	74	Management outlook and Functional compatibility
24	Average time required for process of returning the defective, incomplete or damaged orders and reshipping of the order to customer	75	Ethical standards
25	Package cycle time	76	Designing capabilities
26	Product release process cycle time	77	Development capabilities
27	Installation cycle time	78	EDI Capabilities
28	Sourced/in process product requisition cycle time	79	Manufacturing/process capabilities
29	Product / grade change over time	80	Customer concentration
30	Intra production re-plan cycle time	81	Political stability
31	Quarantine/hold time	82	Cultural similarity
32	Production engineering cycle Time		**Safety metrics**
	Flexibility metrics	83	Number of lost time accidents
33	Time for expediting delivery and transfer process.	84	Recordable incident rate
34	Cost of expediting delivery and transfer process.	85	Dollars spent in worker Compensation
35	Ability to augment return capacity rapidly	86	Safety training
36	Upside order flexibility	87	Safety audits
37	Downside order flexibility		**Environmental metrics**
38	Upside production flexibility	88	Conventional pollutants released to water
39	Downside production Flexibility	89	Ambient air releases
40	Upside delivery flexibility	90	Hazardous/ non-hazardous waste
41	Downside delivery flexibility	91	Chemical releases
42	Upside installation flexibility	92	Global warming gases
43	Downside installation Flexibility	93	Ozone depleting chemicals
44	Upside shipment flexibility	94	Bio accumulative pollutants
45	Downside shipment flexibility	95	Indoor environmental releases
46	ECO cycle time	96	Resource consumption
	Cost and financial metrics	97	Non-renewable resource Consumption
47	Inventory turns	98	Recycled content
48	Payment terms	99	Product disassembly potential
49	Return policy	100	Product durability
50	Warranty costs	101	Component reusability
51	Landed cost		

In Table 4, we present a comparative study of the frequency of use of partner selection criteria between 1966 and 2010. This study was conducted by Thiruchelvam and Tookey [41].

Table 4. Comparison of selection attributes (1966-2001 and 2001-2010)

#	Criterion	Frequency (1966-2001)	Frequency (2001-2010)	Overall
1	Quality*	71	37	108
2	Delivery*	75	36	111
3	Performance history*	11	10	21
4	Warranties and claim policies*	1	5	6
5	Production facilities and capacity*	35	20	55
6	Price*	81	37	118
7	Technical capability*	30	24	54
8	Financial position*	15	17	32
9	Procedural compliance*	4	0	4
10	Communication system*	7	7	14
11	Reputation and position in industry*	10	8	18
12	Desire for business*	2	2	4
13	Management and organization*	17	22	39
14	Operating controls*	5	0	5
15	Repair service*	18	11	29
16	Attitude*	14	6	20
17	Impression*	6	4	10
18	Packaging ability*	5	4	9
19	Labor relations record*	4	6	10
20	Geographical location*	17	12	29
21	Amount of past	1	2	3

#	Criterion	Frequency (1966-2001)	Frequency (2001-2010)	Overall
	business*			
22	Training aids*	3	0	3
23	Reciprocal arrangements*	5	0	5
24	Reliability	NA	11	11
25	Flexibility	NA	19	19
26	Process improvement	NA	12	12
27	Product development	NA	19	19
28	Environmental and social responsibility	NA	9	9
29	Occupational safety and health	NA	4	4
30	Integrity	NA	5	5
31	Professionalism	NA	4	4
32	Just in time (JIT)	NA	5	5
33	Commitment	NA	9	9
34	Economy situation	NA	1	1
35	Long-term relationship	NA	4	4
36	Political situation	NA	2	2

Based on this study of partner selection criteria, we concluded that these criteria have evolved. For this reason, we focus on changing criteria and try to identify the criteria that may be used in 2020. The main objective is to be able to add criteria adapted to the collaborative context (i.e. design).

IV. CRITERIA USED IN 2020

Our current work focuses on selecting criteria that may be used in the year 2020. To identify the list of criteria that will be used in 2020 for the selection of industrial suppliers, we proceeded in the following way:

Firstly, we performed advanced research and we identified most of the criteria that have been used since the 1960s (41 criteria). They are listed in Table 5.

Secondly, we contacted more than 50 managers from international companies from the five continents asking them to rank a list of criteria. These international companies are located in different countries listed by alphabetical order: Australia, Azerbaijan, Canada, Egypt, France, Italy, Ivory Coast, the Kingdom of Saudi Arabia, Morocco, Poland, Romania, Spain, Switzerland, Tanzania, the United Arab Emirates, the United Kingdom, the United State of America, and Vietnam. The professional people who have been contacted, have chosen a score from 1 to 5, where 1 is the least important criterion, and 5 being extremely important. The criteria are all listed in the following table:

Table 5. The list of all criteria

#	Criteria	#	Criteria
C1	Ability to exchange information	C22	Production skills
C2	Ability to meet quality specifications consistently	C23	Program quality management
C3	Ability to meet specified delivery schedules	C24	Respect of environmental criteria
C4	Ability to meet your packaging requirements for their product	C25	Respect of social criteria
C5	Attitude toward your organization	C26	Supplier sourcing strategies
C6	Compliance with tendering procedures	C27	Technological capability (including research and development facilities)
C7	Conceptual capacity	C28	Political stability: Political stability and relations with the exporting country
C8	Control operations	C29	Ethical standards
C9	Delivery reliability	C30	Payment terms
C10	Financial capacity and stability	C31	Warranties
C11	Geographic location	C32	Warranty costs: Warranty costs include materials, labor and problem diagnosis for product defects
C12	Internal organization	C33	Safety training: Procedures and practices regarding safety training and level of awareness
C13	Price of the product	C34	Designing capabilities of new product
C14	Occupational health and safety systems	C35	Company size
C15	Years of experience	C36	Negotiability, flexibility with regards to cost, payment terms, return policies and similar other terms and conditions in supplier – buyer contract
C16	Performance history	C37	Return policy: Suitability of policies regarding return of the defective, damaged or incomplete orders
C17	Product purchase process	C38	Just in time (JIT)
C18	Quality of product	C39	Long-term relationship
C19	Quality of Delivery	C40	Number of lost time accidents
C20	Repair services	C41	Other partners (Costumers of the partner)
C21	Reputation and industrial positions		

Our main objective is to help companies use recent and current criteria. These criteria are classified by our study and will help the decision-maker to select the best suppliers. If the decision-makers use a high number of criteria, the enterprise should spend time and money to classify the best supplier. For this reason, we proceed to reduce this number of criteria.

V. DATA ANALYSIS

The following table lists the data results of the evaluation of the criteria ranked by the professionals (managers of international enterprises):

Table 6. Descriptive Statistics of the scores

	Average	Standard deviation	Minimum	Maximum
C18	4.40	1.12	1	5
C2	4.24	1.05	1	5
C3	4.12	1.13	1	5
C9	4.04	1.17	1	5
C19	3.96	1.02	1	5
C39	3.88	0.97	2	5
C22	3.80	0.87	2	5
C5	3.76	0.83	2	5
C31	3.76	0.97	2	5
C1	3.68	1.18	1	5
C13	3.68	0.99	2	5
C24	3.68	0.95	2	5

	Average	Standard deviation	Minimum	Maximum
C10	3.64	0.99	2	5
C23	3.64	0.99	2	5
C32	3.60	1.19	0	5
C4	3.56	0.96	2	5
C8	3.56	1.33	0	5
C27	3.56	0.82	2	5
C14	3.52	1.19	1	5
C16	3.52	1.00	2	5
C20	3.52	1.00	1	5
C29	3.52	0.96	2	5
C21	3.48	1.12	1	5
C38	3.48	0.82	2	5
C25	3.44	0.77	2	5
C28	3.44	0.82	2	5
C30	3.40	1.00	1	5
C34	3.40	1.19	2	5
C36	3.40	0.91	2	5
C12	3.36	1.04	1	5
C33	3.32	1.07	1	5
C17	3.28	0.98	1	5
C6	3.24	1.09	1	5
C15	3.24	1.13	1	5
C37	3.24	1.16	0	5
C7	3.20	1.00	1	5
C26	3.16	1.14	1	5
C40	3.16	1.31	0	5
C41	3.00	1.26	0	5
C11	2.92	1.08	1	5
C35	2.68	1.14	1	5

To test if any of the criteria were ranked higher or lower than the others, we will use the Friedman test that is a non-parametric statistical test. This test is the alternative of the Repeated-Measures ANOVA that is performed on ordinal (ranked) data.

In this test, the hypothesis is: There is a difference in the ranks of the 41 criteria.

With error $\alpha = 0.05$, df = k – 1 = 40, $\chi 2 = 149.92$, P-value = 1.28e-14. The decision is to accept the hypothesis; therefore, there was a statistically significant difference in the ranking of the criteria. Not all of them were ranked in the same way.

To rank the criteria, we will use Kendall's W test.

Table 7 shows the ranks of the different criteria sorted from the most to the least important:

Table 7. Ranks of the criteria

Rank	Criteria	Mean Rank
1	C18	31.66
2	C2	29.30
3	C3	28.50
4	C9	28.08
5	C19	26.06
6	C39	25.84
7	C22	24.22
8	C5	23.70
9	C31	24.50
10	C1	23.60
11	C13	23.32
12	C24	22.32
13	C10	22.42
14	C23	22.44
15	C32	22.76
16	C4	20.58
17	C8	23.56
18	C27	21.40
19	C14	21.60
20	C16	21.08
21	C20	21.04
22	C29	20.10
23	C21	20.66
24	C38	19.80
25	C25	19.28
26	C28	19.78
27	C30	18.98
28	C34	19.50
29	C36	19.42
30	C12	18.22
31	C33	17.94
32	C17	17.32
33	C6	17.66
34	C15	16.96
35	C37	17.48
36	C7	17.82
37	C26	16.72
38	C40	17.56
39	C41	14.48
40	C11	12.44
41	C35	10.90

It is clear from the previous table that the most important criterion is C18 (Quality of product), and this is not an unexpected result. The second most important criterion was C2 (Ability to meet quality specifications consistently; here again we see the focus is on quality - consistent quality to be specific. The third most important criterion was C3 (Ability to meet specified delivery schedules); here we see the focus is on the schedule.

VI. DISCUSSION

After having found the previous results, different aspects can be discussed, such as the used method, the criteria, and the suppliers' specifications.

On the criteria: we proposed criteria but the managers could not formulate others, or more significant ones, and therefore it introduces several biases. As criteria are defined using a few words, we cannot control the managers' interpretation so that their scores may be influenced by this interpretation. Moreover, we did not verify if the managers' criteria are well taken into account: this would have limited the interpretation bias. In the future we should treat this with semantic approaches to avoid this bias.

On the method side, we have applied the chosen statistical approach using the same weight for all the criteria. However, it may be interesting to couple this study with a semantic analysis to detect proximities of meaning (based on similarity measurement techniques) and obtain a different weighing of for certain criteria. Another point is to evaluate the weight directly with the managers when they proceed to the prioritization.

Concerning the specificities of suppliers, we have made the assumption here that all suppliers have the same role. But in design for example, we will have suppliers with different roles: the ones who provide a technology, the

ones who manufacture in addition to studying, the one who specializes in geopolitical questions, etc... We then think about studying subsets of criteria with more dedicated criteria associated with role definition/partnership type and adapted weights. We can generalize this principle depending on the area of activity of the company, and thus the type of product to be developed. These ideas will be developed in our future research work.

VII. GENERAL CONCLUSION AND PERSPECTIVES

Supplier selection processes are very important for the organization in order to make good choices. These processes can vary from one company to another depending on many factors. One of these factors is the dependence on the criteria of the company itself according to its needs.

This paper has focused on industrial supplier selection criteria. We have presented a detailed state of art overview of the selection criteria defined between 1960 and 2018. This work gave a big set of criteria. In our study, we present to the attention of decision-makers, the best criteria that may be used in 2020. We concluded that most categories of main Selection Criteria for Industrial Suppliers which will be used in 2020 are: quality, consistent quality, delivery, Long-term relationship, Warranties, Ability to exchange information. This optimization of the number of criteria that may be used in 2020, ensures an easy application of supplier selection methods, and thus optimizes the amount of resources used for finding suppliers.

In our future work, different points can be studied later to improve the results. In fact, we conducted a survey with industrialists from different fields. It is important to specify our statistics in a specific industrial field in order to establish specific results (by specific domain).

In the second phase, we will try to regroup the criteria in sets according to the semantic distances that separate them. The goal is to reduce significantly the number of used criteria.

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