TRENDS IN METALLURGICAL SUPPLIERS' SELECTION AND EVALUATION

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Abstract

The aim of the article is to research approaches and trends in the supplier selection and evaluation process in the metallurgical industry with focus on sustainable and resilience assessment. A systematic literature review of scientific articles containing case studies of selection and evaluation of metallurgical suppliers was chosen as a research method. The research has proved that the conventional approach to supplier selection and evaluation is still prevalent in the metallurgical industry. However, the importance of the sustainable and resilient criteria is gradually increasing.

Keywords: Metallurgy, supplier selection and evaluation, sustainability, resilience

1.   INTRODUCTION

Supplier selection and evaluation is one of the important processes of metallurgical supply chain management. It is crucial for a reliable and efficient supply of materials and raw materials. For the selection and evaluation of suppliers are mainly used sets of conventional criteria and their evaluation by means of scoring methods. However, today's turbulent and globalized business environment requires new approaches in supplier relationship management (see e.g. [1-3]). The basic trends in this area include assessing the sustainability and resilience of suppliers. Also, supplier selection and evaluation methods move from simple scoring methods to advanced multi-criteria decision making (MCDM) methods. The aim of the article is to research approaches and trends in the supplier selection and evaluation process in the metallurgical industry. A systematic literature review of scientific articles containing case studies of selection and evaluation of metallurgical suppliers was chosen as a research method.

2.   THEORETICAL BASE AND RESEARCH METHOD

Nowadays, there are two leading trends in the supply chain management: sustainability and resilience. The following definitions were used in the research work and the article:

- Supply chain sustainability is an ability of the supply chain to balance its economic, environmental and social performance.
- Supply chain resilience is an ability of the supply chain to return to its original state after its serious disruption, i.e. to its original performance.

The systematic literature review was conducted on the basis of the full text scientific articles from the following databases: ProQuest, ScienceDirect, and SpringerLink. We searched for articles that included a real case study focused on the MCDM based selection and evaluation of suppliers from the metallurgical industry. A total of ten articles were identified, but two of them used the same data for the case study (see **Table 1**). All the case studies were categorized into four groups (see column Approach):

1)   Fully conventional (FC) approach - all used selection and evaluation criteria are conventional (e.g. criteria related to quality, price, delivery, technology).

2) Mostly conventional (MC) approach - most of the criteria are conventional, but there are some criteria related to sustainability and/or resilience. The case studies do not categorize the criteria into conventional, sustainable and/or resilient groups.

3) Conventional-sustainable (CS) approach - the case studies include criteria categorized into two groups: conventional and sustainable.

4) Conventional-sustainable-resilient (CSR) approach - the case studies contain criteria divided into three groups: conventional, sustainable, and resilient.

The metallurgical suppliers can be in two positions (see column Suppliers):

1) Metallurgical producer's supplier - a metallurgical producer selects and evaluates its suppliers (raw materials suppliers).

2) Metallurgical supplier - a customer selects and evaluates its metallurgical suppliers (metallurgical products suppliers).

Table 1 also contains MCDM methodology used, the number of the selection and evaluation criteria used and the number of the selected and evaluated suppliers.

Table 1 Researched case studies and their basic description

No.	Approach	Author(s), year, source	Suppliers	Methodology	No. of criteria	No. of suppliers
1	FC	Kumar et al., 2018 [4]	Iron and steel producer's suppliers (Raw materials)	Fuzzy TOPSIS	5	4
2	MC	Kumar et al., 2019 [5]	Steel suppliers (Pipes)	Taguchi loss function, AHP, TOPSIS	4	4
3		Tahiri et al., 2008 [6]	Steel suppliers	AHP	6	4
4		Punniyamoorthy et al., 2011 [7]	Steel suppliers (Structural sections)	Structural equation modelling, fuzzy AHP	10	5
5		Kumar et al., 2014 [8]/Jain et al., 2016 [9]	Steel suppliers (Tubes)	DEA	9	18
6		Kar, 2015 [10]	Steel producer's suppliers	Fuzzy AHP, neural networks	6	54
7		Cieśla, 2016 [11]	Aluminum suppliers	Score weighted method	7	5
8	CS	Mohammed et al., 2019 [12]	Metal producer's suppliers (Raw materials)	Fuzzy multi-objective optimization, fuzzy AHP, fuzzy TOPSIS, TOPSIS	10	3
9	CSR	Amindoust, 2018 [13]	Metal producer's suppliers	Fuzzy set theory, DEA	12	8

The selection and evaluation criteria used in the researched case studies were classified into three groups: conventional, sustainable, and resilient. Global Reporting Initiative (GRI) standards were used to identify sustainable criteria [14]. The standards define sustainability topics for three sustainability dimension: economic, environmental, and social (see **Table 2**). Criteria identified as sustainable were classified according to the scheme. However, three criteria were so general that they could not be assigned to the sustainability topics and have its original name: environmental competencies, environmental management system, and information disclosure.

Table 2 GRI sustainability topics [14]

Economic dimension	Environmental dimension
Economic performance	Materials
Market presence	Energy
Indirect economic impacts	Water
Procurement practices	Biodiversity
Anti-corruption	Emissions
Anti-competitive behavior	Effluents and waste
	Environmental compliance
	Supplier environmental assessment
Social dimension	
Employment	Rights of indigenous peoples
Labor/management relations	Human rights assessment
Occupational health and safety	Local communities
Training and education	Supplier social assessment
Diversity and equal opportunity	Public policy
Non-discrimination	Customer health and safety
Freedom of association and collective bargaining	Marketing and labelling
Child labor	Customer privacy
Forced or compulsory labor	Socioeconomic compliance
Security practices	

The supply chain resilience capabilities defined by Pettit et al. [15] were used to identify and classify resilient criteria:

- Adaptability - ability to modify operations in response to challenges or opportunities.
- Anticipation - ability to discern potential future events or situations.
- Capacity - availability of assets to enable sustained production levels.
- Collaboration - ability to work effectively with other entities for mutual benefit.
- Dispersion - broad distribution or decentralization of assets.
- Efficiency - capability to produce outputs with minimum resource requirements.
- Financial strength - capacity to absorb fluctuations in cash flow.
- Flexibility in order fulfilment - ability to quickly change outputs or the mode of delivering outputs.
- Flexibility in sourcing - ability to quickly change inputs or the mode of receiving inputs.
- Market position - status of a company or its products in specific markets.
- Organization - human resource structures, policies, skills and culture.
- Recovery - ability to return to normal operational state rapidly.
- Security - defense against deliberate intrusion or attack.

- Visibility - knowledge of the status of operating assets and the environment.

3. RESULTS AND DISCUSSION

3.1. General results

We can deduce the following research results based on information from **Table 1**:

- Most of the researched case studies is based on MC approach. There is only one with CS and one with CSR approach, no based on conventional-resilient approach. This shows that the conventional approach to supplier selection and evaluation is still prevalent in the metallurgical industry. On the other hand, selected sustainable and/or resilient criteria are increasingly being introduced into the conventional system.
- From a methodological point of view, the investigated authors offer systems of selection and evaluation of metallurgical suppliers based mainly on the AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) MCDM method. At the same time, they offer their combination with fuzzy set theory.
- The number of criteria used in the researched case studies varies between 4 and 12. This shows that it is not appropriate to use too many criteria that reduce the clarity of the supplier selection and evaluation process. On the other hand, using a CSR approach naturally requires a higher number of criteria.
- Although most case studies assessed a relatively small number of suppliers, two of them show that the number of suppliers is not a limiting factor in the application of MCDM methods for the supplier selection and evaluation process.

3.2. The most important criteria for metallurgical supplier selection and evaluation

Table 3 summarizes results of the analysis of criteria occurrence and their classification in the researched case studies. Overall, the table shows that conventional criteria are most often used. The most frequent are the following criteria in that group:

- delivery capability,
- quality,
- logistics cost,
- price,
- technological capability,
- location,
- relationship.

In the group of sustainable criteria, the most common are:

- economic performance (economic dimension),
- environmental management system (environmental dimension),
- occupational health and safety (social dimension).

Finally, in the group of resilient criteria:

- financial strength,
- capacity.

Table 3 Criteria classification and occurrence

Group	Sub-group	Criterion	Case study									Frequency
			1	2	3	4	5	6	7	8	9	
Conventional		Availability							x			1
		Communication system					x	x				2
		Delivery capability	x	x	x	x	x	x	x	x	x	9
		Discipline			x							1
		Location				x	x		x			3
		Logistics cost	x		x	x			x	x	x	6
		Payment terms				x			x			2
		Price		x	x	x	x	x	x			6
		Quality	x	x	x	x	x	x	x	x	x	9
		Relationship		x	x	x						3
		Reputation	x			x						2
		Services		x		x						2
		Shelf life					x					1
		Technological capability			x	x		x		x	x	5
Sustainable	Economic	Economics performance	x		x	x	x					4
	Environmental	Effluents and waste								x		1
		Emission					x			x		2
		Environmental competencies			x						x	2
		Environmental management system				x				x	x	3
	Social	Human rights assessment									x	1
		Information disclosure								x		1
		Occupational health and safety				x				x	x	3
		Training and education								x		1
Resilient		Adaptability			x						x	2
		Capacity			x	x		x			x	3
		Collaboration									x	1
		Efficiency				x						1
		Financial strength			x	x	x	x				4
		Flexibility in order fulfilment				x					x	2
		Flexibility in sourcing									x	1
		Market position							x			1
		Organization				x						1
		Visibility				x						1

4. CONCLUSION

The research has proved that the conventional approach to supplier selection and evaluation is still prevalent in the metallurgical industry. The most common criteria used are delivery capability, quality, logistics cost, and price. However, the following are criteria from the group of sustainable and resilient criteria: economic performance (sustainable group) and financial strength (resilience group). A surprising finding is that relatively little attention is paid to environmental criteria, although the metallurgical industry is one of the largest polluters.

It is very interesting to compare the results with other industries. While there are a relatively large number of CS or CR based case studies in other sectors (we found ten CS based case studies and three CR base studies from other industries), the study no. 9 is the only one that uses a CSR approach across all sectors. This represents a major research gap in the process of selecting and evaluating industrial suppliers.

The case studies use mainly fuzzy AHP and/or fuzzy TOPSIS methods. However, supplier selection and evaluation criteria are very often interdependent. Thus, future research work should focus rather on ANP (Analytic Network Process) or fuzzy ANP methodologies.

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