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Sustainable suppliers evaluation in the waste management sector: the case of a leading Sicilian enterprise

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Abstract:
Sustainable waste management is a fundamental service within the concept of smart cities development as well as social welfare and economic growth. With this recognition, the careful preliminary screening and consequent selection of reliable green suppliers is crucial. This process should be formalised and performed with relation to the various commodity sub-sectors that are relevant for companies operating within the field of reference. To such an aim, the present paper approaches the problem of supplier selection by proposing a Multi-Criteria Decision-Making (MCDM) model based on the integrated use of the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS). Such a methodological combination has been widely and successfully proposed in literature for the supplier selection problem. However, to the best of the authors' knowledge, this is the first time that the mentioned MCDM tool is applied to suppliers of a real company operating in the waste management sector and according to pre-defined commodity sub-sectors of interest. This study aims to also highlight the different importance of technical, economic and environmental aspects towards a sustainable optimisation of such a fundamental city service as waste management is.

Keywords:
Waste Management; Suppliers Evaluation; Optimization and Decision-Making; AHP; TOPSIS.

1. INTRODUCTION AND OBJECTIVES

The global need of responsible production and consumption models is declared by the UN 2030 Agenda for sustainable development, where the idea of integrated sustainability emerges as a concept to be pursued at environmental, economic and social level. In such a complex and interconnected business context, the adoption of sustainable practices and systems is crucial to go beyond the mere company boundaries by involving the whole supply chain and by promoting economic and safety conditions for workers as well as transparent procurement and legality targets. Technical, economic and organizational quality requirements characterising the supplier evaluation process of companies are more and more supported by the operational assessment of social, ethical and environmental factors. By keeping the main parameters of reference, modern processes of evaluation and selection of suppliers increasingly aim to measure their degree of performance also according to environmental and social criteria. With this regard, it is interesting to understand why corporate social and environmental responsibility are becoming so important for improving the global quality of supplies.

Not only does the value of companies lie in the excellence of products and services, but it also refers to the capability of building and maintaining relationships with all the stakeholders (i.e. customers, shareholders, employees, non-governmental organizations, trade associations, trade unions, government observers, and so on). Literature demonstrates as an effective supply chain management represents a significant strategic issue. Indeed, sharing ethical and social values greatly helps to strengthen entrepreneurial relationships, something that simplifies competition in extremely diversified and global markets.

This paper focuses on the problem of supplier selection in the waste management sector for smart cities by promoting innovation and considering the value of sustainability. This research has been carried out in collaboration with the Italian leading company Dusty Srl, which operates in the territory of Catania city, located in the region of Sicily. The research is organised as follows. Section 2 reports the literature review while section 3 defines the proposed approach along with methodological details. Section 4 introduces the company and provides the practical application for the discussed decision-making problem. Section 5 closes the work by proposing potential future lines of research.

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2. LITERATURE REVIEW

Core services innovation is undoubtedly the driving engine of urban economic development. As discussed by Wang and Deng (2021), information technology is the key source to solve complex urban problems as well as to lead urban development in terms of optimization and decision-making in smart city control. In this context, increasing concerns refer to resource use efficiency, pollution, waste management and materials security (Palafox-Alcantar et al. (2020); Rogers et al. (2017)). Incorporating effective waste management while developing smart cities helps to protect the environment as well as to enhance health and social wellness of individuals Koraganji et al. (2022).

Innovating the decision-making process of suppliers evaluation for waste management contributes to add great value to general business results. The adoption of a Multi-Criteria Decision-Making (MCDM) approach can have high strategic impact towards the structured formalisation of this process and the enhancement of its output. As asserted by Zyoud and Fuchs-Hanusch (2017), the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) are two important branches of the decision-making field, offering significant examples of the diverse applications of MCDM methods in conjunction with varied disciplines.

On the one hand, AHP is a useful and flexible decision-support tool which allows to converge to a shared decision among different stakeholders expressing their judgments of preference about pairs of various elements of analysis (Benítez et al. (2018, 2019)). On the other hand, TOPSIS can be effectively used to get a structured ranking of decision-making elements. Apart from the flexibility of application, one of the main strength of this method consists in its logic of proximity to ideal and in the ability to deal with even huge sets of alternatives (Gul and Yucesan (2021)) in need of being ordered according to the evaluation of differently weighted criteria. This combination of methods has been widely used for suppliers evaluation purposes. For instance, Marzouk and Sabbah (2021) developed an application in the field of construction supply chain. Kumar et al. (2019) proposed an integrated model for objective assessment of suppliers for a heavy locomotive firm. The techniques have been also proposed in their fuzzy versions in order to better manage uncertainty of input evaluations (see Junior et al. (2014); Beikkhakhian et al. (2015); Mathew et al. (2020), among others).

The novel contribution of our research to the current state of the art is mainly of practical nature. A well-recognised MCDM integrated tool is applied for the first time to innovate the process of supplier selection for a real leading company in the waste management sector. Such application follows the implementation of a formal qualification process of suppliers, which considers the presence of barrier criteria defined by the same company under study. We focus on the environmental aspect among other relevant criteria, having attracted growing interest in literature and practice on supplier selection for waste management (Prosman and Sacchi (2018)). We lastly propose a structured definition of commodity sub-sectors for the waste management field as a part of the qualification process, in order to establish suitable categories of suppliers.

3. MATERIALS AND METHODS

This section describes the relevant elements of the problem as well as the methodological details on the basis of which we are going to carry out our analyses. We aim to establish the procedure leading to qualify and select suppliers, that will be based on their specific commodities sectors (CS) and on a set of suitable evaluation criteria (EC). This procedure will be performed through two stages:

- qualification process, made of the following steps:
  (1) defining commodity sectors and related sub-sectors;
  (2) formalising the presence of barriers and thresholds;
  (3) establishing the set of criteria for suppliers selection;
- multi-criteria selection, made of the following steps:
  (4) attributing weights to evaluation criteria via AHP;
  (5) applying the TOPSIS to rank and select suppliers.
  (6) developing a sensitivity analysis on criteria weights.

3.1 Qualification process

The preliminary qualification process has to reflect the specific features of the company under study. This stage is aimed at defining the commodity sectors and related sub-sectors as relevant areas for suppliers categorisation in the field of waste management, as reported in Table 1.

Table 1. Commodity sectors defining suppliers

Main sector	**Sub-sector**
$\mathbf{CS}_1$ Vehicles	• $\mathbf{CS}_{11}$ Purchase of vehicles; • $\mathbf{CS}_{12}$ Rental of vehicles; • $\mathbf{CS}_{13}$ Purchase of substituting parts;
$\mathbf{CS}_2$ Equipment	• $\mathbf{CS}_{21}$ Work equipment; • $\mathbf{CS}_{22}$ Purchase of accessories;
$\mathbf{CS}_3$ Dumpsters and rubbish bags	• $\mathbf{CS}_{31}$ Bags for waste sorting; • $\mathbf{CS}_{32}$ Service materials; • $\mathbf{CS}_{33}$ Service, cloth and under-sink bags; • $\mathbf{CS}_{34}$ Containers, bins, dumpsters, tanks;
$\mathbf{CS}_4$ Clothing	• $\mathbf{CS}_{41}$ Work clothing and personal protective equipment (PPE);
$\mathbf{CS}_5$ Fuel and lubricant	• $\mathbf{CS}_{51}$ Service stations; • $\mathbf{CS}_{52}$ Lubricant suppliers;
$\mathbf{CS}_6$ Maintenance	• $\mathbf{CS}_{61}$ Vehicle maintenance; • $\mathbf{CS}_{62}$ Equipment maintenance; • $\mathbf{CS}_{63}$ Other maintenance;
$\mathbf{CS}_7$ Training	• $\mathbf{CS}_{71}$ Compulsory training; • $\mathbf{CS}_{72}$ Professional/Technical training; • $\mathbf{CS}_{73}$ Other specialised training;
$\mathbf{CS}_8$ Services	• $\mathbf{CS}_{81}$ Production services; • $\mathbf{CS}_{82}$ Professional services; • $\mathbf{CS}_{83}$ General services;
$\mathbf{CS}_9$ Other supplies	• $\mathbf{CS}_{91}$ Street furniture; • $\mathbf{CS}_{92}$ General purchases; • $\mathbf{CS}_{93}$ Utilities; • $\mathbf{CS}_{94}$ Advertising and promotion; • $\mathbf{CS}_{95}$ Insurance; • $\mathbf{CS}_{96}$ Other personnel supplies; • $\mathbf{CS}_{97}$ Use of third party assets; • $\mathbf{CS}_{98}$ Various management costs; • $\mathbf{CS}_{99}$ Tangible and intangible assets; • $\mathbf{CS}_{910}$ Property lessors.

The goal of the qualification process will be the formalisation of a shortlist of candidate suppliers, by means of the identification of barriers on the highlighted sub-sectors and of suitable thresholds on qualification indicators. This will allow to formalise the list of actually eligible suppliers.

Barriers and thresholds will have to be evaluated according to the regulation in force and to the specific mission of the company as well as to the reputation it aims to build and maintain. Potential barriers for supplier selection within the sub-sectors reported in Table 1 could be, for example, inadequate requirements in certifying procedural transparency aligned with excellent legality standards. Another barrier may refer to the implementation of not sustainable policies throughout the supply chain from the supplier side, and so on. Furthermore, the qualification process will be based on the respect of minimum requirements in terms of numerical indicators. In such a direction, thresholds will have to be established on the chosen qualification indicators, since they may vary for suppliers according to the commodity sector of reference. For example, stricter indicators can be requested to suppliers belonging to the commodity sector CS_1 (vehicles) with respect to suppliers belonging to the CS_8 (services), and so on.

Once having defined commodity sectors, sub-sectors, barriers and having established proper thresholds on qualification indicators, it will be indispensable to create a correlation between these indicators and evaluation criteria, as main drivers of analysis. The main criteria are listed, codified and comprehensively described in Table 2.

Table 2. Evaluation criteria

Criterion	Description
EC$_1$ Compliance	This criterion includes scores for issues related to compliance, potential conflicts of interest, anti-mafia certifications and privacy requirements.
EC$_2$ Safety & Security	This aspect considers the accomplishment of fundamental requirements of health and safety for workers and the organisation of related measures.
EC$_3$ Training	This criterion takes into account the attribution of scores related to the formalisation of suitable training processes for the involved resources.
EC$_4$ Certifications & Management	This criterion evaluates scores for quality certifications and relevant aspects of integrated business management.
EC$_5$ Sustainability	The following areas are evaluated: environment, air, water, land, customers.
EC$_6$ Planning Cost	It contemplates as score the possibility to plan cost through price catalogues.

As previously touched, the output of the qualification process will be the shortlist of eligible suppliers which actually respond to the specific company needs and requirements. This will constitute the input of the multi-criteria selection along with the set of established evaluation criteria.

3.2 Multi-criteria selection

In this subsection we provide procedural details about the MCDM-based approach herein proposed for selecting suppliers. The application is aimed at first weighting the previously mentioned criteria. This will be done according to the specific company priorities and, specifically, by involving a selected group of decision-makers. Secondly, the calculated weights will be used for ranking suppliers. We herein specify that this stage will be iterated for each commodity sub-sector. Indeed, suppliers have to be analysed with relation to their specific area of competence.

AHP weighting criteria AHP faces complex problems by first decomposing and representing them through a hierarchy structure. The elements belonging to the same level of the structure are pairwise compared with the help of an expert subject or a decision-making group. Comparisons are expressed by numerical values translating specific linguistic evaluations. We are herein using the nine-point scale proposed by Saaty (1977) and reported in Table 3.

Table 3. Saaty scale

Values	Pairwise comparisons
1	Equal importance of two items
3	Moderate importance of one item over another
5	Strong importance of one item over another
7	Very strong importance of one item over another
9	Extreme importance of one item over another
2,4,6,8	Intermediate evaluations
Reciprocals	Values of inverse comparisons
Decimals	Values of intermediate importance

Judgments of pairwise comparisons elicited for a set of k elements can be collected into a $k \times k$ matrix $X = (x_{ij})$, called Pairwise Comparison Matrix (PCM). The goal of the problem consists in calculating those numerical values $w_1, \ldots, w_k$ which represent the priorities of the elements according to the elicited comparisons x_{ij}. If these evaluations have been performed in a completely consistent way, relations between weights w_i and comparisons x_{ij} are given by $w_i/w_j = x_{ij}$ $(i, j = 1, 2, ..., k)$, and the PCM X is said to be consistent. In such a case, the leading eigenvalue of the matrix is equal to k, and the priority vector expressing the mutual importance of elements can be calculated by normalising the Perron eigenvector Saaty (2000). However, given the natural lack of consistency of human thinking, some degree of inconsistency is always expected and, as a result, the reciprocal PCM X is generally not fully consistent. The eigenvalue problem has to be solved for non-consistent PCMs, that is $X\mathbf{w} = \lambda\mathbf{w}$. This aims to achieve λ_{max} as the unique largest eigenvalue of matrix X which gives the Perron eigenvector as an estimate of the priority vector. The AHP developed by Saaty admits some degree of inconsistency in each set of judgments elicited by human experts. It indeed provides a measure of consistency through the so-called *consistency ratio* CRs:

$$CR = \frac{CI}{RI}, \tag{1}$$

where CI is the *consistency index*, and RI is the *random index*. For matrices of order k, CI can be defined as follows:

$$CI = \frac{\lambda_{max} - k}{k - 1}, \tag{2}$$

Furthermore, Saaty (2000) provided average consistencies (RI values) of randomly generated matrices (see Table 4).

Table 4. Random index values

k	2	3	4	5	6	7	8	9	10
RI	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

On the whole, a value of $CR \leq 0.1$ indicates acceptable consistency. However, should the CR value be higher than this threshold, judgments of pairwise comparison may not be reliable and should be reconsidered either elicited again.

TOPSIS ranking suppliers The application of the TOPSIS method aims to highlight those alternatives representing the best trade-off according to all the considered criteria. These alternatives have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. These are two ideal solutions identified for the problem under study, respectively representing the best and the worst scores potentially assumed by alternatives under each criterion. Quantitative evaluation of alternatives under criteria are first collected and normalised to then compute the geometric distances between each alternative and the mentioned positive and negative ideal solutions. To such an aim, the preference directions of criteria need to be previously established. It means that we have to specify if criteria need to be maximised (e.g. criteria related to safety or reliability) or minimised (e.g. criteria representing costs). It is possible to consult such works as (De Anchieta et al. (2021), Brentan et al. (2022)). TOPSIS can be applied by implementing the next steps (Hwang and Yoon (1981)).

- Drawing up the input assessment matrix by collecting quantitative evaluations g_{ij} of alternative i under each criterion j.
- Computing the normalised matrix, where the generic element z_{ij} represents the normalised evaluation of the generic alternative i under criterion j:
$$z_{ij} = \frac{g_{ij}}{\sqrt{\sum_{i=1}^{n} g_{ij}^2}}. \quad (3)$$
- Computing the weighted and normalised matrix, being the generic element u_{ij} determined as:
$$u_{ij} = w_j \times z_{ij}, \forall i, \forall j; \quad (4)$$
w_j representing the weight of criterion j, previously attributed.
- Calculating the positive and the negative ideal solutions, respectively A^* and A^-, via the following equations:
$$A^* = (u_1^*, \dots, u_k^*) = \left\{(\max_i u_{ij} | j \in I'), (\min_i u_{ij} | j \in I'')\right\}; \quad (5)$$
$$A^- = (u_1^-, \dots, u_k^-) = \left\{(\min_i u_{ij} | j \in I'), (\max_i u_{ij} | j \in I'')\right\}; \quad (6)$$
I' and I'' being the sets of criteria to be, respectively, maximised and minimised.
- Calculating the geometric distances from each alternative i to the positive ideal solution A^* and to the negative ideal solution A^-, respectively indicated as distances S^* and S^-, as follows:
$$S^* = \sqrt{\sum_{j=1}^{k} (u_{ij} - u_{ij}^*)^2}, i = 1, \dots, n; \quad (7)$$
$$S^- = \sqrt{\sum_{j=1}^{k} (u_{ij} - u_{ij}^-)^2}, i = 1, \dots, n. \quad (8)$$
- Determining, for each alternative i, the closeness coefficient C_i^* which indicates how alternative i performs with respect to the two ideal solutions:
$$C_i^* = \frac{S^-}{S^- + S^*}, 0 < C_i^* < 1, \forall i. \quad (9)$$
- Achieving the final ranking of alternatives by ordering them according to decreasing values of closeness coefficients. For example, with relation to two generic alternatives i and z, if $C_i^* \geq C_z^*$ then solution i has to be preferred to solution z.

4. REAL CASE STUDY: DUSTY SRL

This case study implements the procedure optimising the process of suppliers evaluation for the company Dusty Srl.

4.1 General setting

Dusty Srl is an Italian Limited Liability Company operating since 1982 by providing municipal administrations with both general urban hygiene and special services (Table 5).

Table 5. General and special services

Type	Service provided by Dusty Srl
General services	• collecting and transporting unsorted waste; • separating glass, paper, plastic and cans, organic, green and bulky waste; • removing special and hazardous waste; • cleaning and disinfecting roads, public spaces and market areas; • purging cockpits and road drains; • managing and controlling ecological platforms for waste delivery; • mechanically and manually cleaning public areas; • cleaning sandy shores and public beaches; • cleaning parks, public gardens and green areas.
Special services	• decontaminating infected sites (Dusty manages the whole process from the preliminary investigations to the management and execution of the activities); • removing asbestos (Dusty's specialized technicians design and manage dedicated sites for the safe removal of both compact and brittle products).

The 2020 social report records a revenue of 95 millions (€) and 1,407 employees, who are distributed in twenty operational departments. The company is registered in the National Register of Environmental Managers (ID number PA0397) and achieved the following certifications: Quality Management System UNI ISO 9001: 2015 (no. 3156); Environmental Management System UNI EN ISO 14001: 2015 (no. 6801); Occupational Health and Safety Management System ISO 45001: 2018 (no. 28812); Anti-bribery Management System UNI ISO 37001: 2016 (no. 0062); Social Accountability SA8000: 2014 (no. IT20/0543).

It goes without saying, sustainability is one of the most important organisational values for Dusty, which declares to be a company at the service of the environment. The management of business processes along with the use of available resources is led by principles of eco-efficiency and rationalization. For instance, Dusty produces renewable energy generated by its own wind and solar power plants. The company operates through the use of specialized tools capable to support various social responsibility actions in a sustainable way. In the short-medium term, Dusty aims to become part of the so-called B-Corp companies, which are required to meet rigorous standards in terms of social and environmental impact. With this regard, Dusty has been working since the year 2020 on the B-Impact Assessment, that is a management tool supporting companies in assessing their impact on stakeholders (workers, communities, customers, environment stakeholders, and so on). A dedicated internal committee is monitoring the degree of achievement of sustainability objectives.

4.2 Qualification and selection of suppliers

Dusty Srl has already implemented an online platform by means of which suppliers can register and the scores achieved for each of the criteria described in Table 2 can be collected. Upon the registration phase, the qualification process aims to define the shortlist of eligible suppliers. Dusty considers as barrier criteria EC_1 (compliance) and EC_2 (safety & security). This means that those suppliers who do not match Dusty's strict requirements in terms of anti-corruption and anti-mafia as well as of safety and security organisation are directly discarded and *a priori* excluded from the selection process. The selection process hence focuses on reduced sets of suppliers for each of the considered commodity sub-sectors, and considers the diverse weights attributed to the remaining criteria: EC_3 (training), EC_4 (certifications &management), EC_5 (sustainability) and EC_6 (planning cost). The weights have been herein calculated by means of the AHP. In particular, seven stakeholders from the purchasing function and in charge of other functions have been involved for pairwise comparing criteria. In the case of inconsistent evaluations, consistency of PCMs has been achieved through the negotiation process developed by Carpitella et al. (2021).

Table 6. Aggregated matrix, priorities and CR

PCM	EC_3	EC_4	EC_5	EC_6	w	CR
EC_3	1	0.5397	0.4471	0.5765	14.68%	
EC_4	1.8530	1	0.7742	0.6256	23.21%	0.0126
EC_5	2.2366	1.2917	1	0.7873	29.24%	
EC_6	1.7346	1.5985	1.2702	1	32.87%	

Values translating judgments elicited by stakeholders have been then aggregated by means of the geometric mean and reported in Table 6, along with the resulting weights in percentage. Prominent importance has been attributed, respectively, to the criteria of planning cost and sustainability, while certification & management and training have associated lower importance. Once calculated criteria weights via AHP, the TOPSIS has been applied to get the final ranking of suppliers. The procedure has been iterated for all of the sub-sectors of Table 1 and different rankings have been obtained to allow the company to easily discriminate among the specific type of services offered. To exemplify results, just the ranking of suppliers of commodity sub-sector CS_{11} "purchase of vehicles" has been reported (Table 7) while other ones have been omitted because of the limited space allowed. Table 7 associates a codified ID to each supplier for privacy reasons and specifies scores accumulated through the qualification process along with the C_i^* values resulting from the TOPSIS application. In detail, it is possible to observe that twenty-seven suppliers had originally applied for evaluation within sub-sector CS_{11}. Five of them (SSP_{014}, SSP_{016}, SSP_{025}, SSP_{026}, SSP_{027}) are not qualified (NQ) for the procedure, because they did not satisfy barrier criteria EC_1 (compliance) and EC_2 (safety & security) defined in Table 2.

4.3 Sensitivity analysis and managerial insights

A sensitivity analysis has been performed by varying criteria weights. In detail, the following three scenarios of weights (S_1, S_2, S_3) have been contemplated:

Table 7. Suppliers' ranking for sub-sector CS_{11}

Supplier/ int.score	**EC_3** $0-6$	**EC_4** $0-64$	**EC_5** $0-178$	**EC_6** $0-12$	C_i^* **value**	**Ranking position**
SPP_{001}	3	44	76	12	0.7140	5^{th}
SPP_{002}	4	29	78	12	0.6905	6^{th}
SPP_{003}	0	15	48	0	0.1750	18^{th}
SPP_{004}	4	15	96	0	0.3121	14^{th}
SPP_{005}	0	5	40	0	0.0953	21^{st}
SPP_{006}	2	41	94	12	0.7376	3^{rd}
SPP_{007}	5	25	112	0	0.3873	10^{th}
SPP_{008}	6	34	134	0	0.4562	8^{th}
SPP_{009}	5	22	158	12	0.8001	1^{st}
SPP_{010}	4	27	36	0	0.2746	15^{th}
SPP_{011}	2	0	44	0	0.1195	20^{th}
SPP_{012}	3	16	104	0	0.3214	12^{th}
SPP_{013}	6	38	94	0	0.4176	9^{th}
SPP_{014}	—	—	—	—	—	**NQ**
SPP_{015}	6	35	166	0	0.4956	7^{th}
SPP_{016}	—	—	—	—	—	**NQ**
SPP_{017}	3	10	48	0	0.1793	17^{th}
SPP_{018}	3	0	36	0	0.1279	19^{th}
SPP_{019}	6	25	102	12	0.7362	4^{th}
SPP_{020}	2	6	16	0	0.0937	22^{nd}
SPP_{021}	2	28	118	12	0.7458	2^{nd}
SPP_{022}	6	25	70	0	0.3333	11^{th}
SPP_{023}	2	17	42	0	0.1931	16^{th}
SPP_{024}	5	28	54	0	0.3127	13^{th}
SPP_{025}	—	—	—	—	—	**NQ**
SPP_{026}	—	—	—	—	—	**NQ**
SPP_{027}	—	—	—	—	—	**NQ**

- **S_1**: $w_{EC_3} = 19.68\%, w_{EC_4} = 28.21\%, w_{EC_5} = 34.24\%, w_{EC_6} = 17.87\%$;
- **S_2**: $w_{EC_3} = 19.68\%, w_{EC_4} = 28.21\%, w_{EC_5} = 14.24\%, w_{EC_6} = 37.87\%$;
- **S_3**: $w_{EC_3} = 24.68\%, w_{EC_4} = 33.21\%, w_{EC_5} = 19.24\%, w_{EC_6} = 22.87\%$.

In the first two scenarios, we have respectively decreased the weights of the most significant criteria EC_5 and EC_6 of a quantity equal to 0.15 while increased the other weights accordingly. In the third scenario, we have increased the weights of EC_3 and EC_4 of 0.1 each while reduced the other weights accordingly. Results derived from the sensitivity analysis are reported in Table 8. It is possible to observe as the supplier to be preferably selected may vary by varying the importance attributed to the considered criteria by the involved decision-making panel of the company Dusty Srl. For example, apart from the baseline scenario (Table 7), supplier SSP_{009} represents the best choice in scenario S_1, while supplier SSP_{001} occupies the first position for scenarios S_2 and S_3, that is when sustainability criterion has associated lower weights. Not only does the proposed MCDM application contribute to streamline the process of selection, but it also guarantees the maximum transparency throughout the whole decision-making process. Indeed, the proposed approach allows the company to make use of a structured and reliable mathematical tool capable to consider the different importance of criteria.

5. CONCLUSIONS AND FUTURE RESEARCH

The present paper proposes the combined application of two reliable decision-making methods, that are the AHP and the TOPSIS techniques, to optimise the process of supplier evaluation for a real leading company, Dusty Srl.

This company operates in the waste management sector, which represents a crucial aspect for smart city control, being aimed at promoting social awareness and economic

Table 8. Sensitivity analysis on criteria weights

$\mathbf{S}_1$	C_i^*	$\mathbf{S}_2$	C_i^*	$\mathbf{S}_3$	C_i^*
$\mathbf{SPP}_{009}$	0.7429	$\mathbf{SPP}_{001}$	0.8138	$\mathbf{SPP}_{001}$	0.7403
$\mathbf{SPP}_{015}$	0.6782	$\mathbf{SPP}_{006}$	0.7924	$\mathbf{SPP}_{006}$	0.7128
$\mathbf{SPP}_{019}$	0.6584	$\mathbf{SPP}_{019}$	0.7818	$\mathbf{SPP}_{019}$	0.7062
$\mathbf{SPP}_{006}$	0.6581	$\mathbf{SPP}_{002}$	0.7754	$\mathbf{SPP}_{009}$	0.6967
$\mathbf{SPP}_{021}$	0.6559	$\mathbf{SPP}_{009}$	0.7692	$\mathbf{SPP}_{002}$	0.6830
$\mathbf{SPP}_{001}$	0.6378	$\mathbf{SPP}_{021}$	0.7470	$\mathbf{SPP}_{021}$	0.6485
$\mathbf{SPP}_{008}$	0.6335	$\mathbf{SPP}_{015}$	0.4256	$\mathbf{SPP}_{015}$	0.5962
$\mathbf{SPP}_{002}$	0.5919	$\mathbf{SPP}_{013}$	0.4179	$\mathbf{SPP}_{008}$	0.5769
$\mathbf{SPP}_{013}$	0.5725	$\mathbf{SPP}_{008}$	0.4113	$\mathbf{SPP}_{013}$	0.5765
$\mathbf{SPP}_{007}$	0.5338	$\mathbf{SPP}_{022}$	0.3488	$\mathbf{SPP}_{007}$	0.4865
$\mathbf{SPP}_{022}$	0.4545	$\mathbf{SPP}_{007}$	0.3444	$\mathbf{SPP}_{022}$	0.4815
$\mathbf{SPP}_{012}$	0.4298	$\mathbf{SPP}_{024}$	0.3424	$\mathbf{SPP}_{024}$	0.4707
$\mathbf{SPP}_{024}$	0.4219	$\mathbf{SPP}_{010}$	0.3148	$\mathbf{SPP}_{010}$	0.4280
$\mathbf{SPP}_{004}$	0.4203	$\mathbf{SPP}_{004}$	0.2618	$\mathbf{SPP}_{004}$	0.3689
$\mathbf{SPP}_{010}$	0.3646	$\mathbf{SPP}_{012}$	0.2499	$\mathbf{SPP}_{012}$	0.3537
$\mathbf{SPP}_{023}$	0.2555	$\mathbf{SPP}_{023}$	0.2068	$\mathbf{SPP}_{023}$	0.2801
$\mathbf{SPP}_{017}$	0.2407	$\mathbf{SPP}_{017}$	0.1829	$\mathbf{SPP}_{017}$	0.2522
$\mathbf{SPP}_{003}$	0.2248	$\mathbf{SPP}_{003}$	0.1678	$\mathbf{SPP}_{003}$	0.2218
$\mathbf{SPP}_{018}$	0.1726	$\mathbf{SPP}_{018}$	0.1410	$\mathbf{SPP}_{018}$	0.1909
$\mathbf{SPP}_{011}$	0.1560	$\mathbf{SPP}_{020}$	0.1167	$\mathbf{SPP}_{020}$	0.1576
$\mathbf{SPP}_{020}$	0.1269	$\mathbf{SPP}_{011}$	0.1045	$\mathbf{SPP}_{011}$	0.1442
$\mathbf{SPP}_{005}$	0.1196	$\mathbf{SPP}_{005}$	0.0686	$\mathbf{SPP}_{005}$	0.0930

growth by pursuing process innovation. Dusty Srl has adopted the approach making use of AHP and TOPSIS as a regular best practice and this application has contributed to enhance the whole process of supply chain management. The definition of barrier criteria as well as of such relevant aspect as sustainability have been integrated into the model, and suitable commodity sectors have been formalised for the preliminary categorisation of suppliers.

Future developments of this paper will regard the integration of the proposed approach within procedures of risk management and environment optimisation along with the development of expert-based materiality analyses.

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