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ELECTRE applied in supplier selection – a literature review

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Abstract

Decision models play an important role in helping people and organizations make the best possible decision with the information and data available. One of the most important steps to business growth is supplier selection, and, regarding this topic, decision models are very useful. An incorrect supplier selection could cause financial and operational problems for a company. In addition to reducing purchase costs and improving market competitiveness, choosing the right suppliers improves user satisfaction. In this context, this study presents a literature review on a multi criteria decision model called ELimination and Choice Expressing REality (ELECTRE) applied to supplier selection. Twenty-two studies were reviewed and characterized in terms of which ELECTRE method was applied, in which industry was applied, and if it was integrated or compared with another model. The results revealed that ELECTRE is not applied solely often, and is commonly applied in hybrid manner, merged with other methods, such as AHP and TOPSIS, and these types of application result in a more robust outcome. The gathered results can lead to managers and researchers to take a deeper dive into this marginally explored topic.

Keywords: Multiple criteria decision making (MCDM); ELECTRE; Supplier selection; Literature review

1. Introduction

One of the most vital parts in performing activities, whether it is daily activities or more rare and important ones, is the decision-making process. There are situations where decisions may be obvious, however there are more complex

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ones that may comprise conflicting criteria which should be taken in consideration simultaneously, with different priorities and degrees of importance, in order to make a reasonable decision [1]. One of these activities can be supplier selection (SS) by a company or organization. SS can be defined as the process in which organizations identify, screen, evaluate, analyze, and contract with their suppliers and, as any process, it requires resources, mainly human and finance. A manufacturing firm's success depends on the selection of its suppliers. Choosing adequate suppliers is a multi-criteria decision-making process that could be vital for most organizations [2]. SS is a concept rooted in the early days of commerce. It is an activity that started as the establishment of business relationships between buyers and suppliers. Later, the concept evolved as an important area of Supply Chain Management (SCM), intrinsic to procurement and sourcing process. The process of selecting the optimal supplier is a complex decision that has a direct impact on a company's financial flow, profitability, and unveils its environmental stance [3]. This complexity grows as crucial is the supplied item. While for low-cost and low-specific items the SS is not critical, for items that have high financial impact and complex SC networks the SS is a strategic aspect of SCM [4].Opting for the right suppliers brings about a substantial reduction in material procurement expenses and enhances a company's competitive edge. Consequently, numerous experts assert that supplier selection stands as the paramount function within a procurement department [5]. Due to its importance, SS has been thoroughly studied throughout the years in the context of supply chain, production, decision sciences and operations management [6].

Supplier selection and evaluation have been extensively addressed in the literature using various models and techniques [7]. There are systematic reviews on the topic, such as Chai, Liu, and Ngai (2013) [8], that deeply studied the development of decision-making (DM) techniques in SS through a systematic review that regards literature published between 2008 and 2012. There are other reviews such as Zimmer et al. (2016) [9] that involved a sustainability and environment frame in their study, which has been a tendency in the last years, as Schramm et al. (2020) [10] might prove, and others that already focus on innovation, specifically on industry 4.0 [6]. Zimmer et al. (2016) [9], for instance, studied 143 articles published between 1997 and 2014 and mainly covered decision processes like AHP, ANP and fuzzy-based approaches [6].

Supplier selection is a MCDA problem that often contains imprecise or uncertain information such as demand, quality, cost, capacity and decision makers' judgments [3]. With ELimination and Choice Expressing REality (ELECTRE), rating and weighting of supplier selection criteria in the problem are assessed using linguistic variables, which is a popular approach of multiple-criteria decision-making (MCDM) [2]. Analyzing dominance relations among alternatives is the focus of ElECTRE, as it exploits notions of concordance to study outranking relations. Alternatives can be compared using these outranking relations [12]. A non-compensatory logic is used in the ELECTRE method to study outranking relationships [13], which makes it distinct form other MCDMs. Methods of outranking such as ELECTRE are used to handle uncertainty and imprecision in the decision-making process [14].

ELECTRE [15] allows to support decisions that present several criteria, as is the case of SS. This decision model permits to model decision-making preferences, categorize alternatives (i.e., suppliers in a SS problem) and, furthermore, provides a robust setting by permitting to conduct sensitivity analysis on the model's results. However, analysing the current literature, to the best of our knowledge, no literature review has been made on ELECTRE models applied in supplier selection so far.

This review analyzes 42 articles, all of them applying ELECTRE methods on SS, comparing the usage of ELECTRE with other solutions such as AHP or fuzzy-logic or even mixing ELECTRE with these other solutions. We attempt to answer the following questions: (1) Do the ELECTRE methods prove useful for supplier selection in any kind of organization? (2) Is it better to apply ELECTRE by itself or along with other MCDA methods (e.g., AHP)? (3) Does ELECTRE prove to be more fitted to supplier selection problems than other methods?

2. Methods

2.1. Search process and eligibility criteria

In this study, the *Preferred Reporting Items for Systematic Reviews and Meta-Analyses* (PRISMA) is used. With PRISMA a minimal set of items should be reported in systematic reviews and meta-analyses based on evidence. Searches for the study were performed using the string "TITLE-ABS-KEY ("ELECTRE" AND "supplier")". This

string was used to retrieve only the relevant studies regarding supplier selection with ELECTRE. The word selection was not used in the string to include papers that used the words, such as, evaluation, election or picking. The papers were collected on SCOPUS database. This database was chosen due to the credibility and reliability it has in the scientific community. The studies sought were submitted to a selection process that followed the following steps:

1. Insert the string in the databases.
2. Records were screened.
3. Applying a filter to retrieve only records from Journals.
4. Applying a filter to withdraw papers published in 2015 and after.
5. Analyzing the title, abstract and content to eliminate papers that did not incorporate the ELECTRE model in the context of supplier selection and excluding reports that were not related with Engineering or Business.

The process above is illustrated in Figure 1. The sources for the present article were searched on the 12th of December of 2022. The content of the found papers were examined carefully. Relevant data was retrieved, and group sessions were made to share this information.

Afterwards, all the paper's content was integrated into a table using a MS Excel spreadsheet, which included a column with the main objectives and a summary of the paper's content. The time interval was between 2015 and 2022 a. This is due to the United Nations Conference on Sustainable Development (or Rio20) which happened in 2012. Some topics discussed appealed to sustainable development implementation, as well as sustainable consumption and production [10]. This event allowed the researchers to assume that a few years later (2015), research on sustainable and green supplier selection would be more present in papers.

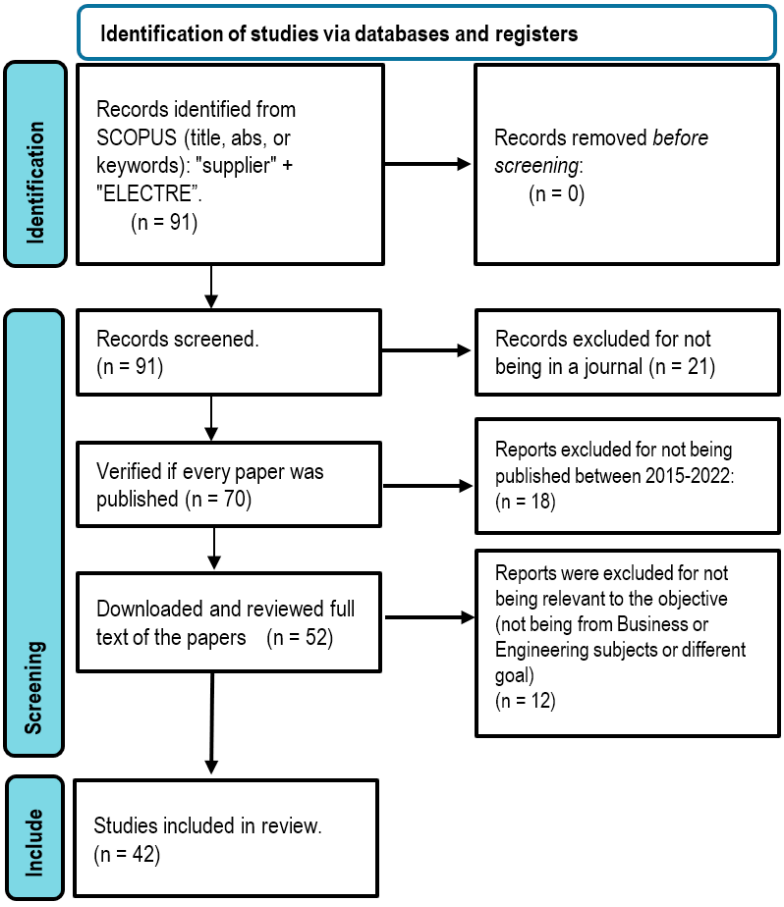

Fig. 1. Selection process of studies according to the PRISMA method.

2.2. Evaluation of research

By analyzing the bibliometric results, the reviewed papers have stagnated and then decreased over the past seven years, as shown in Figure 2, which brought the authors to the conclusion that the ELECTRE methodology is not being intensively researched to be used in the supplier selection topic.

All sources considered were thoroughly analyzed, and the most relevant to this review are shown in Table 1 that can be found at the end of the article. Data retrieved from the studies concerns the following: year of publication; whether a case study is included or not; which ELECTRE method was used; in which industry was it applied; and which model was it integrated with or compared to.

2.3. Study risk of bias assessment

The present paper can contain some bias regarding "supplier selection using ELECTRE" since the reviewed studies are only from Engineering, Business and decision making. Studies that were highly theoretical or had a high degree of calculus were also excluded, since SS was not the focus in such types of studies. Publication bias can also be present because studies that were not published in Journals were not considered.

3. Descriptive Analysis

This research focuses on 42 papers published in well accredited journals, present on SCOPUS between 2015 and 2022. This period was chosen due to the increasingly interest in SS, triggered by the UN Event already mentioned above. The distribution of the analyzed papers over the seven years is presented in Fig. 2.

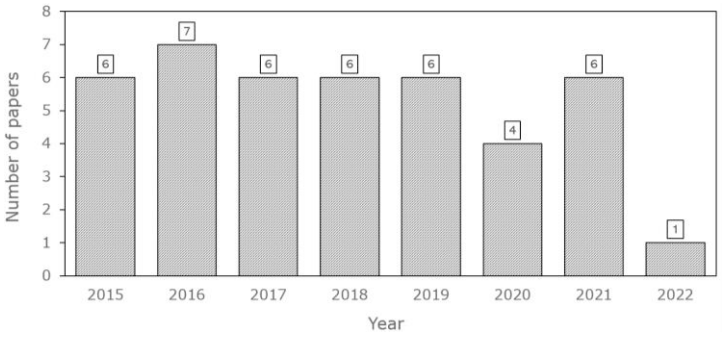

Fig. 2. Distribution of reviewed papers according to publication year.

Another possible consequence of the United Nations Conference on Sustainable Development in 2012, besides the increasing number of papers on the subject, was including social and "green" criteria in every decision-making process tangled in the supply chain management, including Supplier Selection. Within this setting, models or systems of decision making for backing-up SS, bearing in mind a multi criteria outlook, arose as a popular topic.

Once the area of most interest to this study was SS, the scientific areas of the journals where the papers were published did not show high variety, as depicted in Figure 3. The area that does not fit with the subject is Environmental Science, however, once it is a major concern of today's society, as the UN event in Brazil demonstrates, it is understandable and makes total sense it appears as one of the areas attached with SS. Due to this event could also be the reason that the number of papers referring sustainable supplier selection has been increasing over the years [16]. Nevertheless, the study shows that this topic is published in a wide variety of journals, with the majority being published in the Soft Computing and Applied Intelligence (both ~9%).

The ELECTRE methods are not a novelty in literature, therefore there are many methods based on the original that emerged in the 1960's with Roy Bernard [1]. However, it does not show signs of an obsolete model. It is still active in the literature, whether with new models ([17]) or with integrations with other methods, in a hybrid manner, as it can be seen in Figure 4.

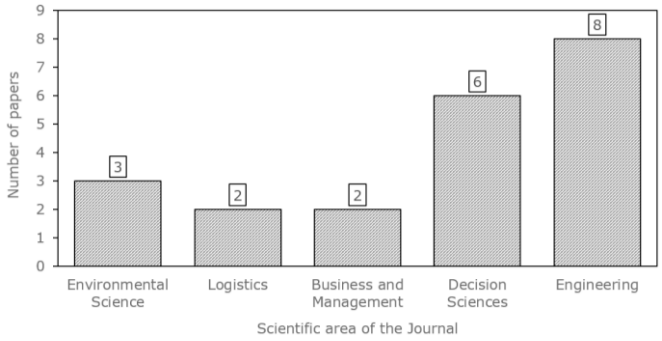

Fig. 3. Distribution of reviewed papers according to journal's area

The methods found in the reviewed data base, that were integrated with ELECTRE, were ABC [18], Analytic Hierarchy Process (AHP) [19],[20], VIKOR [21,22], analytic network process (ANP) [23], [24], fuzzy logic [25], interval type 2 fuzzy numbers [25] and even the Pareto rule (80/20) [26]. Artificial Neural Networks (ANN) [27], bipolar fuzzy set [28], Business ecology theory [29], Best Worst Method (BWM) [30], Fuzzy AHP and TOPSIS [31], only Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [32], and Hesitant Fuzzy sets [33] are also methods used to improve the ELECTRE methodology. Besides integration, there were papers that compared results from ELECTRE with other methods, such as TOPSIS [34],[35], AHP [36], Flow Sort [37], fuzzy AHP and fuzzy TOPSIS [27] and other version of the ELECTRE method.

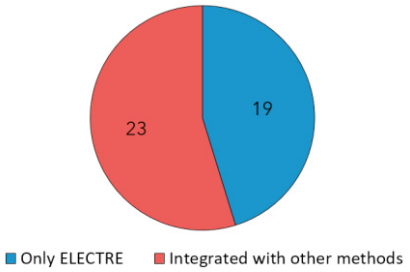

Fig. 4. Distribution of reviewed papers with ELECTRE by itself or integrated with other methods.

The selection of suppliers is a problem inherited from almost every type of business. Supply chain is paramount everywhere, across all industries. For that reason, it is predictable that the case studies regarding MCDM in SS are very heterogeneous in terms of sector, as it shows in Fig.5.

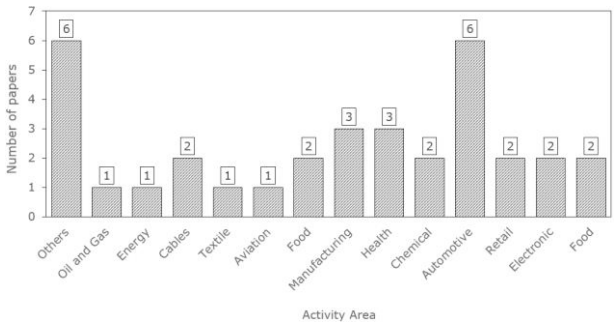

Fig. 5. Distribution of the reviewed papers by case study's area.

4. Discussion

The MCDA area is consolidated, with a significant number of methods and authors. Within the scope of the subject of this study (supplier selection), we observed many cases that apply ELECTRE methods. However, it is perceived

that the ELECTRE methods are not the solution that first comes to mind of quite a few authors to the detriment of AHP, TOPSIS and fuzzy logic methods, for example. Having said that, the papers that compare ELECTRE with other methods tend to prioritize the other methods, suggesting that ELECTRE would be used in the first instance, with the objective of limiting the options of the problem and opening the way to apply the next method. In this regard, ELECTRE can be applied individually or combined with a wide range of diverse techniques in different ways.

The main challenge of this study came from the characteristics mentioned above. The fact that ELECTRE is so often integrated along with other methods makes it difficult to infer the usefulness of ELECTRE by itself versus ELECTRE integrated with other methods. To address this, we decided to analyze the papers separately, thus meaning the capacity of ELECTRE by itself was studied disjointedly from the outcomes of ELECTRE being used along with other methods. Another challenge faced in this matter is the volatility of the supply chain itself. The best solution for SS problems is not constant over time, so even if the MCDA methods, which include ELECTRE, reach a conclusion that is the most correct in a certain moment, it does not guarantee the perseverance of that same solution over time. This can prove to be a difficulty when assessing the effectiveness of a method.

Another aspect of the papers that may be presented as a struggle for their analyses is the subjectivity of the process of weighing the criteria used in the problem. This is an aspect that requires detailed knowledge of the industry and details of each specific case. For that reason, there is no escape from this problem and every weight of each criterion was assumed as true in the reality of the decision makers of every analyzed paper. However, several approaches adapt to imprecisions in decision makers' verdicts, integrating Fuzzy Sets Theory and its variations (Interval Type-2 Fuzzy Sets, Intuitionistic Fuzzy Sets, and Hesitant Fuzzy Linguistic Term Sets) and Grey Theory with ELECTRE.

As it was already covered in this paper, there are some articles on the subject with a growing interest after around 2015, pushed by the society's pressure on the environmental issues. The year 2020 had seen a decline in the number of published papers, probably because of the COVID-19 pandemic, that prevented researchers from executing experiments and cases studies on site.

The most cited paper within the reviewed data base has 144 citations and address the supplier selection has a type of hierarchical MCDM problem with 2 level criteria and develops a novel hybrid method integrating TL-ANP (2-tuple linguistic analytic network process) and IT-ELECTRE-II (interval 2-tuple elimination and choice translating reality II) [23]. The following most cited paper has 111 citations and is about a grey based hybrid framework for evaluating the environmental performance of service supply chains that is proposed by integrating grey based methods with ELECTRE and VIKOR approaches. The paper carried out two cases studies to understand the effectiveness of the criteria and method to evaluate environmental performance of service supply chains in the context of a developing country [22]. This heterogeneity of subjects within the most cited studies on the topic demonstrates the fact that ELECTRE is useful in many ways and can be applied in very different contexts.

The topic, however, has been becoming more and more relevant in the context of industry 4.0 and smart manufacturing. Within the context of circular economy implementation in supply chain operations, sustainable supplier selection with MCDM has garnered attention and is being investigated based on industry 4.0 initiatives [38]. Management practice in organizations could consider behavioral and socio-economic realities when applying and implementing these tools and techniques. In light of the increasing awareness of environmental sustainability, it could be useful to improve green factors in industry through MCDM. Choice of metrics, uncertainty modeling, the data source for application, and the validation approach, are all elements that are becoming indispensable in a smart manufacturing environment [11], thus opting for MCDM tools, such as ELECTRE, could be very useful.

5. Conclusion

The thorough and separate analysis of considered papers allowed to refine the deductions about the effectiveness of ELECTRE as a stand-alone method. Hence, it can be safely assumed that this method is indeed a proper method to aid reaching the best suited solution for supplier selection (SS) problems by itself. It has also been compared to other MCDM/A methods and still proven to be a strong contender, once the results from one and the other were comparable. This means that the ELECTRE methods are perfectly feasible and trustworthy.

The integration of ELECTRE along with multiple techniques is popular due to the practical complexity of the problems that regard SS, which lead us to conclude that this is the most effective way of applying ELECTRE. We

found that the papers that used ELECTRE as a preliminary method to exclude certain options before applying other methods such as AHP were able to draw more sustained conclusions. Generally, any method applied is not perfect. Therefore, an integration of multiple methods will lead to more accurate conclusions. In the reviewed papers, a lot of comparisons were drawn with the use of different combinations of methods. After a thorough analysis, using ELECTRE in the first instance provided the most efficient outcome once it removes the least favorable options according to the criteria of the problem. Consequently, we recommend the use of ELECTRE as a preliminary method in MCD problems, more specifically regarding SS situations.

Although comparable, results between ELECTRE and other MCDM techniques may differ from one another. To avoid inconsistent results, it is paramount to comprehend the fundamental differences amongst the methods, before integrating them. Furthermore, it is of high importance to check if the integration of the methods increases the complexity of the approach, thus increasing the difficulty of real-life application. If a model demands substantial cognitive effort, its application can be harmed. Finally, the process for elicitation of criteria's weights is a critical issue in SS and should be put through specialists. This induction stresses the need for further consideration while compensatory methods are being used, such as ELECTRE.

Future work should focus on more depth on the ponderation of weighted criteria used, not only in ELECTRE, but also in every other technique that utilizes a quantitative DM approach. Supplier selection and decision-making problems overall have many MCDM methods to help determine a viable solution. However, the process of weighing the different criteria is still very underdeveloped and dependable on the individual's judgement. This urges the need for more studies and eventual systematic approaches.

Table. 1. ELECTRE methods applied in supplier selection and studies analyzing these application

Ref.	Year	Case Study	ELECTRE method	Industry	Integration with	Compared with
[36]	2015	Yes	ELECTRE III/IV	N/A	N/A	AHP
[21]	2015	Yes	ELECTRE	Food	VIKOR	N/A
[39]	2015	No	Fuzzy ELECTRE III	Electronic	N/A	N/A
[40]	2015	Yes	ELECTRE III	Retail	N/A	ELECTRE II
[37]	2015	Yes	ELECTRE I	Bottling	N/A	FlowSort
[41]	2015	No	ELECTRE TRI-C	Electrical maintenance	TrIFNs	N/A
[23]	2016	Yes	ELECTRE II	Automotive	ANP	N/A
[42]	2016	Yes	ELECTRE	Chemical	N/A	N/A
[43]	2016	No	ELECTRE TRI	Automotive	N/A	N/A
[44]	2016	No	ELECTRE TRI	Automotive	N/A	N/A
[45]	2016	Yes	ELECTRE II	Electronic	ISM, ANP	VIKOR
[14]	2016	No	HFLTS-ELECTRE I	N/A	N/A	N/A
[18]	2016	No	Fuzzy ELECTRE	Building and civil engineering	ABC method	N/A
[46]	2017	Yes	ELECTRE TRI-rC	Chemical	N/A	N/A
[25]	2017	Yes	ELECTRE I	N/A	Interval type 2 fuzzy numbers	IF-ELECTRE
[16]	2017	Yes	Fuzzy ELECTRE	Automotive	N/A	N/A
[26]	2017	Yes	Fuzzy ELECTRE	Health	Pareto	N/A
[32]	2017	No	IVIF-ELECTRE	Automotive	TOPSIS	PROMETHEE, VIKOR
[47]	2017	No	IVHFE-ELECTRE	Automotive	N/A	Fuzzy AHP-TOPSIS, Hesitant fuzzy ELECTRE I and II
[22]	2018	Yes	IF ELECTRE	N/A	VIKOR	IF-TOPSIS

Ref.	Year	Case Study	ELECTRE method	Industry	Integration with	Compared with
[26]	2018	Yes	Fuzzy ELECTRE	Health	Pareto	N/A
[48]	2018	Yes	ELECTRE TRI-nC	Manufacturing	N/A	N/A
[49]	2018	Yes	ELECTRE I	N/A	N/A	ELECTRE II, III, IV, IS
[31]	2018	No	ELECTRE	Food	Fuzzy AHP, TOPSIS	N/A
[29]	2018	Yes	ELECTRE II	Aviation	Business ecology theory	N/A
[50]	2019	Yes	Fuzzy ELECTRE	Cement	N/A	N/A
[51]	2019	Yes	ELECTRE-IDAT	N/A	N/A	N/A
[20]	2019	Yes	ELECTRE Tri	Textile	AHP	N/A
[52]	2019	Yes	ELECTRE TRI-nC	Retail	N/A	N/A
[33]	2019	Yes	ELECTRE TRI-C	N/A	Hesitant Fuzzy sets	SMAA-TRI
[28]	2019	No	ELECTRE II	Business location	bipolar fuzzy set	TOPSIS, ELECTRE I
[53]	2020	Yes	IF ELECTRE	N/A	N/A	Several
[19]	2020	Yes	ELECTRE III/IV	Cables	AHP	N/A
[54]	2020	No	q-ROF ELECTRE	"Novel distance measures"	N/A	q-ROF TOPSIS
[27]	2020	No	Fuzzy ELECTRE	Manufacturing	Artifical Neural Networks	Fuzzy AHP, Fuzzy TOPSIS
[34]	2021	Yes	ELECTRE II	Cables	N/A	TOPSIS
[27]	2021	No	Fuzzy ELECTRE	N/A	N/A	IT2FS-ORESTE
[27]	2021	Yes	Fuzzy ELECTRE	Seafearers performance	N/A	N/A
[35]	2021	Yes	ELECTRE II	Manufacturing	N/A	Electre I, TOPSIS
[55]	2021	Yes	ELECTRE TRI	Energy	N/A	N/A
[24]	2021	No	ELECTRE I	Oil and gas	ANP	N/A
[30]	2022	No	ELECTRE-EDAS	Health	BWM	TOPSIS, MAGDM algorithm

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