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Published in:
Business Strategy and the Environment

DOI:
10.1002/bse.3122

Publication date:
2023

Received: 20 May 2021 | Revised: 31 March 2022 | Accepted: 12 April 2022

DOI: 10.1002/bse.3122

RESEARCH ARTICLE

Business Strategy and the Environment WILEY

Outsourcing logistics operations in circular economy towards to sustainable development goals

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Abstract

One of novel manners to achieve sustainable development is concentrating on circular economy in order to manage greenhouse gas emissions, energy consumption, and waste. It also helps to protect the environment and optimize usage of input resources. The main element of circular economy is closed-loop supply chain which covers both forward and reverse products flows. This study aims to outsource logistics operations in a closed-loop supply chain. An innovative analytical multi-step fuzzy decision-making method is proposed to rank sustainable third-party logistics service providers (3PLSPs). Fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) is first used to evaluate the relationships among the main criteria. Then, fuzzy analytic network process (ANP) is applied to weight the determined set of criteria. In order to develop the hybrid fuzzy DEMATEL-ANP method and to simplify the computation, the expert judgment method is used between the two techniques as a middle step to reduce the number of criteria. As many of the criteria overlap with each other on content and context, expert opinions are used to shortlist and rank the criteria. Finally, the 3PLSPs are ranked through the fuzzy complex proportional assessment (COPRAS) method. To validate the practicability and applicability of the improved decision-making model, a household appliance case study is applied with data obtained from industry experts. In this case, five service providers are considered and ranked, while the first one gets the best score. A sensitivity analysis is performed by altering the criteria weights to validate the proposed approach, data, and the obtained results. In terms business and the environment, this study provides success critical criteria for decision-making problems in circular economy for addressing sustainable development.

KEYWORDS
circular economy, closed-loop supply chain, fuzzy decision-making approach, logistics operations, outsourcing, sustainable development

1 | INTRODUCTION

As time is traveling far into the 21st century, the circular economy is becoming one of the most significant elements of sustainable development (Barreiro-Gen & Lozano, 2020). To define circular economy, Kennedy and Linnenluecke (2022) stated an economic system called a circular economy that pushes against global challenges such as climate change, environment protection, waste management, and pollution control. Due to the way a linear economy is designed and made, a lot of businesses use natural resources to produce goods that ultimately end up converting waste (Govindan, 2022a). So, the circular economy improves their productivity by extending the life cycle of products and materials which is the goal of sustainable development as well. For this purpose, closed-loop supply chain plays a key role in fulfilling circular economy goals. A closed-loop supply chain is a circular form of supply chain in which all the normal and classic supply chain activities are integrated with backward activities in order to not only improve the efficiency of operations but also reduce the rate of wastes. As well as this, due to circular economy's system of restoring and regenerating resources in the industrial and natural ecosystems in which it is embedded, a closed-loop supply chain can improve environmental performance by taking back products to producers and creating least waste. These wastes are produced from end-of-life products and materials (Frei et al., 2020) and consumption (Govindan et al., 2022).

Logistics is the operations parts of supply chains which are generally organized and implemented in a detailed manner (Sun & Li, 2021). A logistics management system is one that coordinates the movement of goods between origins and the destinations (consumption points), so that requirements of customers or corporates can be complied. In other words, logistics is the management of the goods' flow from the origin to the consumption in transportation and business terms to comply requirements of customers, consumers, cooperators, and companies (Gupta et al., 2021; Perotti et al., 2022). The significance of logistics management in a supply chain network is becoming clearer for both managers as well as academic experts. Hence, it can be claimed that to actualize the aims of circular economy by closed-loop supply chain, companies should focus on logistics operations in both forward and reverse flows. These operations are specialized activities which need to be carried out by skillful experts. The reverse logistics is also the backward flow of products at the end-of-life from clients and consumers to manufacturers and producers in order to recover and sale again (Zarbakhshnia et al., 2019). As stated by Jauhar et al. (2021), reverse logistics is described as "The process of planning, implementing, and controlling the efficient, costs effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal." All in all, in order to design a circular economy, reverse logistics must become a part of it. Reverse logistics deals with the process of returning products to their original source for refurbishment, recycling, redistribution, safe disposal, and so on. Figure 1 illustrates a schematic view of a closed-loop supply chain including reverse and forward logistics flow and its activities centers.

Recycling and disposal are the most significant activities among various activities of reverse logistics in the closed-loop supply chain like remanufacturing and reuse which are suitable just for assembled goods. In fact, recycling and disposal are the bases of circular economy in every industry. This is the main reason why all experts believe that reverse logistics is a sustainable and environmentally friendly strategy that causes of not only achieving competitive advantage for companies but also obtaining the purposes circular economy and sustainable development for both companies and societies (Sharma, Govindan, et al., 2021). The concept and background of reverse logistics and closed-loop supply chain are dropping producing expenditures and also final prices for consumers (Ciliberto et al., 2021; Lima et al., 2021). By using this strategy, not only the costs and using the resources will be reduced, but also the environment will be protected owing to the fact that it is an environmentally friendly technique (de Souza et al., 2022; Low & Ng, 2018). Thus, it might be cost-effective firm-wise and present a competitive advantage.

However, companies need a strong and professional team to track their goods and collect them at the end of life from the consumers (Sharma, Kumar, et al., 2021). In addition, they should invest a

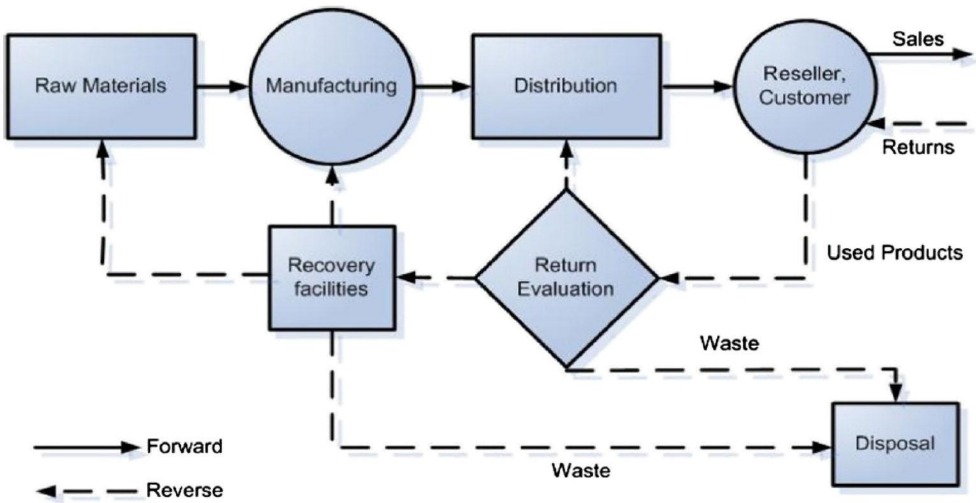


FIGURE 1 A general view of a closed-loop supply chain network (Govindan et al., 2015)

huge budget for buying technological infrastructures and tools and also hiring several employees (Biswal et al., 2018; Stekelorum et al., 2021). Moreover, goods return in reverse logistics is complicated, and the strength of any company's return system depends on its weakest part. Relying on outdated strategies and operations can put a company's reverse logistics system at risk of wasting time and profit. It also can impact on forward logistics system for any goods producer (Cricelli et al., 2021). To solve these professional problems, flexible and scalable solutions for every stage of this process are needed. Hence, the majority of manufacturers opt to outsource their logistics duties to third-party logistics service providers (3PLSPs) to decrease the costs and professionalize the logistics activities which lead to elevate the quality of recovery of delivered second-hand products which can bring the competitive advantages for companies (Laari et al., 2018; Palmieri et al., 2019). Because planning and designing a closed-loop supply chain network including reverse and forward logistics is a complicated and complex task for organizations (Wong et al., 2018; Yu et al., 2022). Yet, choosing an appropriate 3PLSP is needed to protect reputation and popularity from potential risks. In addition to this, a satisfying 3PLSP will be able to increase profitability for clients while lowering operating costs, reducing waste, and providing a high-quality customer experience that protects brands. By selecting a good 3PLSP, a balance can be kept between forward and reverse logistics, given disruption in each of them might be disruption in another. Owing to the above-mentioned reasons, choosing an appropriate 3PLSP is a vital decision-making problem for companies, which can manage the entire logistics network.

In both practice and research, outsourcing reverse and forward logistics simultaneously to the same 3PLSP is not clarified yet. It means that companies which do not have reverse network usually outsource their forward logistics operations. However, companies that ran reverse logistics network only outsource their reverse activities, while the forward flow would manage by their own experts. This important practical gap is also existed in research works of supply chain management. Consequently, it should be obvious how can outsource logistics operations in a closed-loop supply chain network to a 3PLSP to keep a balance between both reverse and forward flows. This is clearly a decision-making problem that needs to be addressed by proposing the following main research question.

- How can be outsourced both reverse and forward logistics operations to a 3PLSP in a sustainable circular economy?

In order to answer the raised main research question, several subquestions would be brought up and then addressed. The main research question that should be investigated in the current study is a practical one, while the potential subquestions may be in practice and theory.

Given various specifications and features that a potential 3PLSP need to have, it can be claimed this is a multi-attribute decision-making (MADM) problem. Also, many experts suggest the MADM techniques for this kind of problem which is carried out the selection process with evaluating several criteria (attributes) in various dimensions (Mavi, Goh, et al., 2017). Thus, identifying the most influential success criteria for selecting the best 3PLSP should be considered as one of the dimensions of this problem. The set of criteria in this problem are categorized into several aspects (main criteria) such as economic, environmental, social, technical, and risk based on relevant literature and experts ideas. So, it might be a potential subquestion to identify the critical success criteria. Given in the decision-making process, the main criteria may influence each other and have interrelation, an approach is needed which can calculate these relations. It means that the cause and effect relations among main criteria in this problem can be computed. Here, increasing the number of criteria lead to increasing to difficulty of calculations. Better put, the more criteria, the more complexity of computations, so an approach is needed to decrease number of criteria. To solve this problem, expert judgment method is applied and is defined as a procedure in which standards and judgments are established by using particular criteria from a science or product field, a particular discipline, an industry, etc. Then, the weights of criteria which can be eligible after applying expert judgment method should computed to use them in the final ranking and selection of 3PLSPs. After achieving the final weights of criteria, 3PLSPs are ranked based on the eligible criteria as the final step of suggested decision-making approach for outsourcing logistics operations in sustainable circular economy. Regarding all the explanations, gaps, and discussion, the proposed subquestions of this study are listed as follows:

- What are the cause and effect relations among the outsourcing logistics operations' influential success criteria using fuzzy DEMATEL?
- How can do a feature (criteria) reduction in process of 3PLSP selection in sustainable circular economy?
- What are the influencing criteria and priority weights of them for the decision of companies in outsourcing logistics operations in sustainable circular economy?
- What is the best 3PLSP among other market competitors?

In order to address the above-mentioned questions, in short, this paper provides an analytical and innovative decision-making model to rank 3PLSPs (alternatives) and select the best one. Because logistics and supply chain management in sustainable circular economy are multi-steps and hierarchical issues in the business analytics including upper and lower zones. As a result, they need analytical approaches for the purpose of analysis and decision-making. First, the fuzzy Decision-Making Trial and Evaluation Laboratory (DEMATEL) is applied to evaluate the interrelation among the main criteria (dimensions). Then, the fuzzy analytic network process (ANP) method is used to weight criteria, since the fuzzy DEMATEL-ANP is one of the most powerful combine MADM techniques for weighting the considered criteria. In fact, the output of fuzzy DEMATEL can be used as the inputs of fuzzy ANP. To improve the fuzzy DEMATEL-ANP method and reduce the complexity of computations, the expert judgment method is applied between two methods to decrease the number of criteria owing to the fact that many of the criteria overlap each other in terms of content and meaning in practice and operations. Improving the performance of fuzzy DEMATEL-ANP technique by applying expert judgment method is actually the theoretical contribution of the current study. Consequently, based on the opinion of experts, criteria are ranked and eliminated nearly half of them by utilizing the expert judgment method. Lastly, 3PLSPs will be ranked by using fuzzy complex proportional assessment (COPRAS) technique. The sensitivity or robustness of the results of the suggested model is checked with a sensitivity analysis including 38 different scenarios.

The developed analytical MADM method is structured for a household appliance case study. This company aims to run a reverse logistics network for its supply chain, and its managers have decided to outsource all the logistics activities (reverse and forward operations) because of above-mentioned reasons and weakness in the experience of these types of activities. Given reverse flow of logistics operations is usually missed in Iranian industries and the circular economy is considered as a brick-and-mortar sector when compared with other economic strategies in terms of adoption and implementation, studies like the current one with an Iranian case study are likely to contribute to improve sustainable development, circular economy, and logistics management and may be recycling and waste management in Iran. For that purpose, a meeting has done with several of the company's experts in various fields like logistics and supply chain management, operations, R&D, and so on to prepare an extensive list of the criteria with reviewing the literature and nominate a list of suitable 3PLSPs. The next step is the important level of this decision-making problem which is proposing an analytical MADM approach to use the considered criteria in order to rank the nominated 3PLSPs. The reasons why the current approach is provided are that we are looking for an analytical approach to determine the relations among all the main criteria (dimensions) and subcriteria, which may be quantitative and qualitative, to increase the accuracy of the selection process, and meantime reduces the complexity of computations. An approach that can consider relations among criteria and weight them already exists in the literature as fuzzy DEMATEL-ANP. Yet, we try to diminish the complication of calculations and at the same time verify the accuracy of the decision-making process. Thereby, the fuzzy DEMATEL-ANP is developed by applying the expert judgment method to reduce the number of subcriteria which leads to decreasing the difficulty of computations. Finally, a fuzzy COPRAS method is used to rank the 3PLSPs. The decision-making model is solved with obtained data from questionnaires which fill out by the experts of introduced case study in order to validate the proposed method. By altering the modeling parameters (criteria weights), the sensitivity or robustness of the obtained results by the provided analytical decision-making model is checked.

This paper continues with a literature review in Section 2. The analytical multi-step fuzzy decision-making approach is proposed in Section 3. Section 4 presents the household appliances case study and obtained results. Section 6 indicates the managerial implications. Discussion is Section 5. Section 7 concludes with some future research directions.

2 | LITERATURE REVIEW

Sustainable development considers three dimensions: economic, environmental, and social. Therefore, most of the operations in manufacturing companies in the sustainable area face challenges with the mentioned three (Hong et al., 2019; Marrucci et al., 2022). Today, despite the fact that companies try to get the economic profit of the supply chain, managers and researchers focus on environmental damages and social issues in the supply chain (Zarbakhshnia, Kannan, et al., 2020). As above mentioned, three elements of sustainability are economic, environmental, and social, so they support sustainable development in supply chains (Govindan, Agarwal, et al., 2019). Figure 2 illustrates the concept of sustainability in logistics and supply chain.

Reverse logistics is one of the main tools in sustainable supply chain management and circular economy that can originate a competitive advantage (Frei et al., 2020; Zhang et al., 2018). Reverse logistics, indeed, is the backward flow of products and materials in the supply chain from customers to suppliers (Fattahi & Govindan, 2017; Gholizadeh et al., 2022). In reverse logistics, the end-of-life products are collected and returned to the producers from consumers. Then, the collected end-of-life products are inspected, remanufactured, recovered, recycled, or disposed of based on their quality situation (Darbari et al., 2019; Tapaninaho & Heikkinen, 2022).

Nonetheless, because of high expenditure as well as professional tasks about managing reverse logistics networks, most of the manufacturers prefer to choose a loyal and reliable service provider to outsource their reverse logistics operations. It might be cause of multidimensional benefits for each organization (Govindan, Kadziński, et al., 2019). Wrong actions of 3PLSPs mostly influence corporate's works. There are numerous criteria that should be considered and evaluated in order to manage the logistics network and 3PLSPs in organizations with complex decisions (Yang et al., 2022). To manage these 3PLSPs, there should be a careful balance while looking for the best 3PLSPs (Mavi, Goh, et al., 2017). This strategy (outsourcing) needs a strong and validate decision-making method thanks to the many criteria which should be engaged in the decision-making process. In other words, it is essential to identify suitable and critical

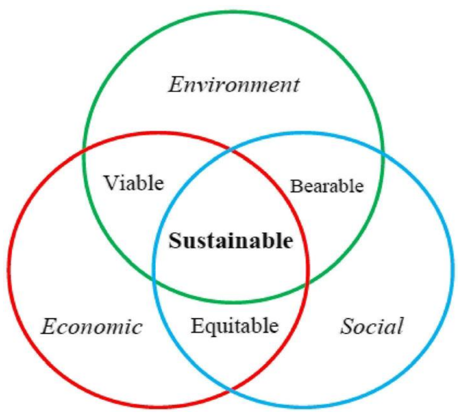


FIGURE 2 Pillars of sustainability (Zarbakhshnia, Wu, et al., 2020)

success criteria for the selection of 3PLSP by a rewarding decision-making approach. Therefore, the two most important matters are considering an efficient set of criteria for evaluating 3PLSPs and proposing an appropriate decision-making approach (Singh et al., 2022).

Recently, some criteria were considered for evaluation of 3PLSPs, and some papers just focused on identifying the critical factors in 3PLSP selection. Oláh et al. (2018) collected the data from 51 Hungarian companies for identifying critical success factors for selecting 3PLSPs by statistical approaches. Their finding introduced IT development as the most considerable factor in this field. Tran and Do (2021) found out the influential successful factors for 3PLSPs selection 218 Vietnamese companies by using exploratory factor analysis and regression analysis. Their results indicated costs and customer service as the most important criteria, while company reputation has the least influence on 3PLSPs selection.

It can be seen that evaluation critical success factors for 3PLSP selection is a separate problem from 3PLSP selection in which just criteria are ranked. Because of different approaches and case studies, these types of studies may lead to different results. Therefore, it would be better to determine the set of criteria for 3PLSPs evaluation from previous studies which were done specifically in the same area. Mavi, Goh, et al., (2017) provided fuzzy SWARA for the first time to weight the determined criteria and then ranked them with respect to the plastic company's expert by fuzzy multi-objective optimization model based on the ratio analysis (MOORA) to outsource reverse logistics activities. They focused on environmental and social such as Capability of R&D, Eco-design, and Respect for local rules and policies more than other criteria. Li et al. (2018) determined organizational functions, cost, and environmental friendliness as the important criteria in 3PLSP selection. They also proposed a new integrated cumulative prospect theory based on a hybrid-information multi-criteria decision making in a fuzzy environment to select the best third-party reverse logistics provider. Liu et al. (2019) prepared a new interval-valued Pythagorean hesitant fuzzy best-worst multi-criteria large group decision-making method consists of the self-organized maps method, the interval Pythagoras hesitant fuzzy set for measuring the considered criteria, and fuzzy best-worst multi to rank the third-party reverse logistics providers. Their model was checked and validated by a mobile phone case study. The worst criteria are degree of closure and cooperation with government agencies, while the best are counted as publicity and education, technique level, cost, and safe recycling Rani et al. (2019) developed a Pythagorean fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method regarding similarity measure in a sustainable environment considering cost, quality, and environmental management system criteria to select the best recycling partner. Bai and Sarkis (2019) considered cost, pollution controls, health and safety, quality, and environmental management system criteria and expanded and integrated theoretically the neighborhood rough set theory two MADM methods as TOPSIS and VIKOR techniques by using sustainable criteria third-party reverse logistics provider selection.

Ou (2020) used the Delphi method to collect the set of considered criteria, and next by using DEMATEL, the set of criteria were evaluated and alternatives (3PLSPs) were ranked. In that research, the greenness of facility and equipment and corporate capability for cost control were provided as the most considerable criteria of a Chinese medical industry which influenced 3PLSPs ranking. Tuljak-Suban and Bajec (2020) proposed a hybrid MADM method including analytic hierarchy process (AHP) and the graph theory and matrix approach for a Slovenian pharmaceutical manufacturers case study that wanted to outsource its logistics operations to 3PLSPs. Regarding the context of the case study, they considered a set of criteria, and the most significant of them were costs, services, and information technology. Liao et al. (2020) combined rough set with based gained and lost dominance score approach for 3PLSPs evaluation in cold medicine and pharmaceutical supply Chain considering criteria such as infrastructure equipment, cost, quality, and service. Liu et al. (2020) provided an integrated MADM approach for outsourcing logistics activities in a cargo business airport in China determining total assets, transport cost, customer satisfaction, personalized service, and technology level as decision criteria. Tu et al. (2021) proposed a model for 3PLSP selection in the healthcare industry based on AHP and weighted density-based hierarchical cluster analysis. They considered service quality, effectiveness, punctuality, and reliability as the key criteria in their selection problem. Qian et al. (2021) suggested a novel prospect theory and Choquet integral with the benefits, opportunities, costs, and risks decision-making framework considering costs and risks factors. Chen, Zhang, et al. (2021) carried out a multiple-perspective MADM for a logistics outsourcing system in a circular economy in fuzzy environment decision-making using cost, green technology capability, health and safety, and revenue from reverse logistics. This model was applied to an automobile manufacturing case study. Sarabi and Darestani (2021) combined MULTIMOORA and BWM in a fuzzy environment for the 3PLSP selection problem. This model was applied to an equipment manufacturing case study in which some criteria were determined delivery, packaging management, and service quality as the most influential criteria.

According to the literature of logistics operations outsourcing and 3PLSP selection, it is obvious that researchers only consider a set of criteria to weight and then based on them select the best 3PLSP among a number of alternatives. However, in this study, we try to combine two separate problems in one, consisting of identifying critical success factors for logistics operations outsourcing in a circular economy and selection of an appropriate 3PLSP. This is a matter which is not found in the relevant literature and essential to be done owing to the fact that solving two problems in a study can be a significant improvement and gap in the study of sustainable supply chain. To do so, a set of criteria are considered by reviewing the relevant literature and idea of the experts who are engaged in this work. Table 1 presents five main criteria: economic, technical, environmental, social, and risk with their subcriteria.

Indeed, these criteria are the three dimensions of sustainability besides the technical and risk aspects. With greater environmental consciousness of people and managers in governments, legislations are in force during two previous decades to protect the environment (Gao et al., 2017). Most firms nowadays need to embrace strategies to

TABLE 1 Criteria of sustainable 3PLSP selection

Main criteria	Subcriteria	Source
C_1: Economic	$C1_1$: Cost	Chen, Duan, et al. (2021), Chen, Zhang, et al. (2021), Liu et al. (2022), Mishra et al. (2022), Pushpamali et al. (2021), Tuljak-Suban and Bajec (2020), Yang et al. (2022)
	$C1_2$: Quality of processes	Chen, Duan, et al. (2021), Chen, Zhang, et al. (2021), Liu et al. (2022), Mishra et al. (2022), Pushpamali et al. (2021), Zarbakhshnia and Jaghdani (2018)
	$C1_3$: Experience	Büyüközkan et al. (2017), Zarbakhshnia et al. (2019)
	$C1_4$: Compatibility in the supply chain	Lui et al. (2019), Sarabi and Darestani (2021)
	$C1_5$: Capability communication	Lui et al. (2019), Mishra et al. (2022), Sarabi and Darestani (2021)
	$C1_6$: Delivery lead time	Chen, Duan, et al. (2021), Pushpamali et al. (2021)
	$C1_7$: Services	Chen, Duan, et al. (2021), Chen, Zhang, et al. (2021), Liu et al. (2022), Tuljak-Suban and Bajec (2020)
C_2: Technical	$C2_1$: Problem-solving capability	Büyüközkan et al. (2017), Lui et al. (2019)
	$C2_2$: Products collecting infrastructure	Büyüközkan et al. (2017), Qian et al. (2021)
	$C2_3$: Product recovery technology	Büyüközkan et al. (2017), Chen, Duan, et al. (2021), Sarabi and Darestani (2021), Yang et al. (2022)
	$C2_4$: IT knowledge	Govindan (2022b), Tuljak-Suban and Bajec (2020)
	$C2_5$: Capability of R&D	Chen, Duan, et al. (2021), Liu et al. (2022), Mavi, Goh, et al., (2017), Mishra et al. (2022), Sarabi and Darestani (2021)
C_3: Environmental	$C3_1$: Energy consumption	Chen, Duan, et al. (2021), Mavi et al. (2018), Tu et al. (2021) Sharma et al. (2022)
	$C3_2$: Eco-design	Chen, Duan, et al. (2021), Liu et al. (2022), Mavi, Goh, et al., (2017), Mishra et al. (2022), Zarbakhshnia et al. (2018)
	$C3_3$: Management of hazardous substances	Chen, Duan, et al. (2021), Mohammed and Wang (2017)
	$C3_4$: Green certifications	Kannan et al. (2022), Mavi et al. (2018), Tu et al. (2021), Zarbakhshnia et al. (2018)
	$C3_5$: Green innovation in recovery process	Chen, Duan, et al. (2021), Chen, Zhang, et al. (2021), Mishra et al. (2022)
	$C3_6$: Environment efficiency	Pushpamali et al. (2021), Yang et al. (2022), Zarbakhshnia and Jaghdani (2018)
	$C3_7$: Environmental-management system	Chen, Duan, et al. (2021), Mishra et al. (2022), Tu et al. (2021), Yang et al. (2022)
C_4: Social	$C4_1$: Health and safety of staff	Bai and Sarkis (2019), Chen, Duan, et al. (2021), Chen, Zhang, et al. (2021), Kannan (2021), Mishra et al. (2022), Yang et al. (2022)
	$C4_2$: Respect for local rules and policies	Chen, Duan, et al. (2021), Liu et al. (2022), Mavi, Goh, et al., (2017), Mishra et al. (2022), Yang et al. (2022), Zarbakhshnia, Wu, et al. (2020)
	$C4_3$: Voice of customer	Govindan (2022c), Mishra et al. (2022), Yang et al. (2022), Zarbakhshnia et al. (2018), Zarbakhshnia, Wu, et al. (2020)
C_5: Risk	$C5_1$: Organizational risk	Qian et al. (2021), Zarbakhshnia and Jaghdani (2018)
	$C5_2$: Financial risk	Mavi et al. (2018), Qian et al. (2021), Yang et al. (2022), Zarbakhshnia et al. (2018)
	$C5_3$: Operational risk	Mavi, Zarbakhshnia, et al., (2017), Qian et al. (2021), Yang et al. (2022)

bring forth economic benefits and to protect natural resources and the environment (Elf et al., 2022; Tseng et al., 2018). Besides, social and technical criteria have a key role in such decision as well as risks criteria. The current world situation shows that flexibility in dealing with risks and disruption is a point that can make businesses alive and resilience. So, the five main criteria that are noted in Table 1 are determined to start this research. To outsource logistics operations in a circular economy and select the best sustainable 3PLSP, an analytical and novel fuzzy decision-making approach is proposed. Since the logistics and supply chain networks are structured analytically and hierarchically with upper and lower zones, the selection partner in these networks should be done with analytical and hierarchical approaches as well. Fuzzy DEMATEL-ANP is used to evaluate the relationship among the main criteria and weights. This technique is developed using the expert judgment method to reduce the number of criteria because of the overlap of several criteria on their content and context in practice and operation which lead to detract the complexity and difficulty of computations. It is also helps decision makers to find out the most influential criteria which can play important roles in these types of decision problems. In the final step, the fuzzy COPRAS method is applied to select the best 3PLSP. The identified gaps and the main contributions of this paper are as follows:

- Indicating how logistics operations in the circular economy can help to accomplish sustainable development goals.
- Providing an innovative and novel analytical multi-step fuzzy decision-making approach for outsourcing both reverse and forward logistics operations to a 3PLSP in a sustainable circular economy.
- Developing the theory of the fuzzy DEMATEL-ANP approach by using the expert judgment method.
- Carrying out a criteria reduction to identify critical success criteria and cause and effect relations among them in the process of logistics outsourcing in the sustainable circular economy.
- Representing how a decision-making model can handle two separate problems, namely, identifying critical success criteria, and alternative selection in a study.

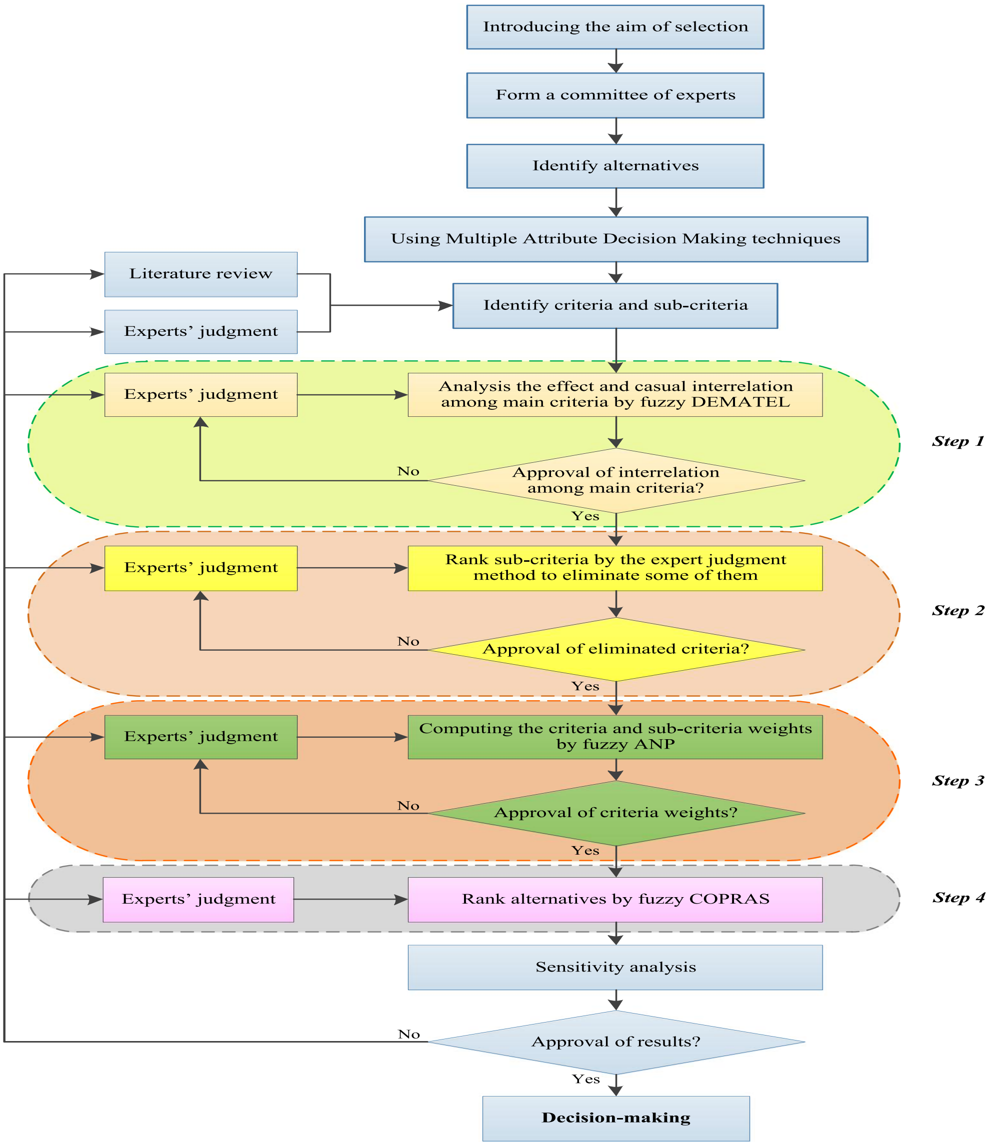
3 | ANALYTICAL MULTI-STEP FUZZY DECISION-MAKING APPROACH

Decision-making problems for selecting the best alternative among several alternatives based on experts' opinions need a specific approach and steps to be fit with determined problem and proposed case study, including defining a suitable set of criteria, weighting the criteria, achieving main values of criteria for each alternative, and assessing alternatives and results (Keršuliene et al., 2010). In this section, an innovative and analytical multi-step fuzzy decision-making approach is introduced step by step. First, main fuzzy operations are introduced and then the fuzzy scales and linguistic terms for fuzzy membership functions are defined (Table 3). Next, improved fuzzy DEMATEL-ANP by expert judgment method is provided to find out relations between the main criteria and weights of them. Then, the fuzzy COPRAS method is presented to rank alternatives of a household appliance case study. Finally, a sensitivity analysis is applied to validate the proposed approach based on alterations in criteria weights and achieved results.

Implementation of sustainable circular economy and reverse flow of logistics operations require a plenty of budget and fund for investment and establish high requirements on technical capabilities. Due to this, there are very few eligible 3PLSPs. When selecting a 3PLSP, experts assess and analyze its criteria based on their information and knowledge, then rank them regarding these results, and choose the best 3PLSP based on its performance. It is important to note that the majority (if not all) influential success criteria are interdependent and interrelated. Due to their qualitative nature, a precise value cannot be attached to their influence. Thus, in this study, fuzzy DEMATEL is used to distinguish the interrelationships of the criteria that influence outsourcing logistics operation's success. There are often qualitative criteria that contribute to the relationships between the decision criteria and subcriteria as a result of such interrelationships. The use of fuzzy numbers to measure qualitative criteria increases the speed of decision making and provides realistic results (Chan et al., 2009). Complex systems can be decomposed using ANP and qualitative and quantitative methods can be combined. The ease of understanding and simplicity of the evaluation process is one reason for the popularity of this method. The ANP structure is a network. This uses a system of pairwise comparisons to measure the weights of the components of the structure. There are two main reasons why ANP is used in this work. First, this method can use the output of DEMATEL, and since we need DEMATEL because of interrelations among main criteria, ANP is our first choice. Second, in contrast to other weighting methods for criteria, which consider the importance or influence of criteria to alternatives and goal of problem, ANP can consider not only all the mentioned relations but consider importance or influence of all criteria to other criteria. As a result, the fuzzy ANP can be utilized to identify the weights of the outsourcing logistics operations' influential success criteria. According to expert evaluations, the COPRAS method determines the optimal and the worst plan among multiple 3PLSPs. By attention to the distance between each plan to the optimal and the worst plan, decisions are made. Finally, the best 3PLSP would be selected. Figure 3 demonstrates the steps of provided analytical multi-steps fuzzy decision-making approach.

In Figure 3 whole, the structure of the current research study is indicated. Before Step 1, the goal of the problem, set of engaged experts, considered criteria, and alternatives of the decision process are determined. These are set based on the experts' ideas and reviewed literature. In Step 1, interrelations (the cause and effect relations) of the main criteria are evaluated by fuzzy DEMATEL. Then, in Step 2, unnecessary criteria are identified and removed by the expert judgment method for the purpose of reduction in complexity of calculation. This is followed by Step 3, in which fuzzy ANP computes the final weights of criteria based on fuzzy DEMATEL results and the ideas of experts. Eventually, in Step 4, alternatives are ranked by fuzzy COPRAS. In each step, if the results would be approved, the next step would be run. Otherwise, it would be corrected based on experts' judgments. At the end of the decision-making process, this result is checked by a proposed sensitivity analysis. If the result would be approved, the decision will be made. Otherwise, it would be sent as feedback to experts to be corrected according to their ideas.

FIGURE 3 Visualization of analytical multi-step fuzzy decision-making approach



3.1 | Preliminaries

In this section, the preliminaries of the proposed decision-making model are introduced. Table 2 provides the list of notation used. Four basic mathematical operations on triangular fuzzy numbers are proposed. Next, the fuzzy scales and linguistic variables are shown in Table 3.

The four basic mathematic operations on triangular fuzzy numbers $A1 = (l_1, m_1, u_1)$, with $l_1 \leq m_1 \leq u_1$, and $A2 = (l_2, m_2, u_2)$ with $l_2 \leq m_2 \leq u_2$, are stated as follows (Santos & Camargo, 2010):

- Fuzzy addition:

$$A1 \oplus A2 = (l_1 + l_2, m_1 + m_2, u_1 + u_2). \quad (1)$$

- Fuzzy subtraction:

$$A1 \ominus A2 = (l_1 - U_2, m_1 - m_2, U_1 - l_2). \quad (2)$$

- Fuzzy multiplication:

$$A1 \otimes A2 = (l_1 l_2, m_1 m_2, u_1 u_2). \quad (3)$$

- Fuzzy division:

$$A1 \oslash A2 = (l_1 / U_2, m_1 / m_2, U_1 / l_2). \quad (4)$$

The fuzzy scales and linguistic variables for fuzzy DEMATEL, fuzzy ANP, and fuzzy COPRAS to turn the qualitative criteria into quantitative criteria based on the conversions listed in Table 3.

Table 3 provides linguistic terms and corresponding fuzzy values for three techniques, while for fuzzy DEMATEL, the linguistic terms are "very high influence," "high influence," "low influence," "very low influence," and "no influence." About fuzzy ANP are "equal importance," "moderate importance," "strong importance," "very strong importance," and "extreme importance." These terms for fuzzy COPRAS are "very low," "low," "medium," "high," and "very high."

TABLE 2 Notation for proposed hybrid MADM approach

Approaches	Symbols	Definitions
Fuzzy DEMATEL	$\tilde{Z}^{(k)}$	Initial direct relation fuzzy matrix.
	$\tilde{Z}_{ij}^{(k)}$	Triangular fuzzy number in initial direct relation fuzzy matrix where k is number of experts.
	$\tilde{\alpha}_i^{(k)}$	Horizontal total value of each criterion in initial direct relation fuzzy matrix.
	$\beta^{(k)}$	Maximum of the upper limit of the horizontal total values of each criterion in initial direct relation fuzzy matrix.
	$\tilde{X}^{(k)}$	Normalized direct-relation fuzzy matrix.
	$\tilde{X}_{ij}^{(k)}$	Triangular fuzzy number in normalized direct-relation fuzzy matrix.
	P	Number of criteria.
	$\tilde{T}$	Total-relation matrix.
	$\tilde{D}_i$	Sum of rows in the total-relation matrix.
	$\tilde{R}_i$	Sum of columns in the total-relation matrix.
Expert judgment method	$\bar{t}_i$	Average criteria value.
	t_{ik}	Rank of criteria i with expert k.
	r	Number of experts.
	q_i	Weights of criteria.
	σ^2	Dispersion of expert ranking.
	β_i	Variation of the gained values.
	W	Correlation coefficient.
	n	Number of criteria.
	T_k	Set of reiterated ranks in rank r.
	S	Total square ranking deviation.
	$x_{a,v}^2$	Compatibility of expert's ideas.
	x_{tbl}^2	Critical tabular value.
Fuzzy ANP	$\tilde{a}_{ij}^{(k)}$	Relative significance of element i compared to element j based on expert k.
	$\tilde{S}_i$	Value of fuzzy synthetic extent.
	$d\left(\tilde{S}_j\right)$	Non-normalized weighted convex fuzzy number.
	W_i	Normalized weight.
Fuzzy COPRAS	$\tilde{X}$	Fuzzy decision matrix where m is the number of alternatives and n is the number of sub-criteria.
	$\tilde{x}_{hj}$	Triangular fuzzy number.
	$\tilde{s}_{hj}$	Ratio of normalization.
	$\tilde{P}_j$	Summation of benefit criteria for each alternative.
	$\tilde{R}_j$	Summation of cost criteria for each alternative.
	$\tilde{R}_{min}$	Low value of $\tilde{R}_j$.
	$\tilde{Q}_j$	Relative significance of each alternative.
	K	High value of Q_j.
	N_j	Percentage of desired of each alternative.

3.2 | Proposed approach

The steps of proposed analytical multi-step fuzzy decision-making approach are as follows:

Step 1: One of the thoroughly structural MADM methods for analyzing the effect and causal relations among a collection of criteria is Fuzzy DEMATEL (Govindan et al., 2021). The fuzzy DEMATEL was proposed by Chou et al. (2012).

TABLE 3 Fuzzy scales and linguistic terms for fuzzy membership functions

Fuzzy DEMATEL (Jeng, 2015)		Fuzzy ANP (Santos & Camargo, 2010)		Fuzzy COPRAS (Mavi, Goh, et al., 2017)	
Linguistic terms	Fuzzy scales	Linguistic terms	Scale of relative importance	Linguistic terms	Triangular fuzzy numbers
No influence	(0, 0.1, 0.3)	Equal importance	(1, 1, 1)	Very Low	(0,0,0.25)
Very low influence	(0.1, 0.3, 0.5)	Moderate importance	(1, 1, 3)	Low (L)	(0,0.25,0.5)
Low influence	(0.3, 0.5, 0.7)	Strong importance	(1, 3, 5)	Medium (M)	(0.25,0.5,0.75)
High influence	(0.5, 0.7, 0.9)	Very strong importance	(3, 5, 7)	High (H)	(0.5,0.75,1)
Very high influence	(0.7, 0.9, 1.0)	Extreme importance	(5, 7, 9)	Very high (VH)	(0.75,1.0,1.0)

Step 1.1: The identified main criteria from literature based on the goal of problem structure the initial direct relation fuzzy matrix ($\tilde{Z}^{(k)}$) by Equation 5. The experts fill the questionnaires using linguistic terms in Table 3 for pairwise comparison to achieve $\tilde{Z}_{(1)}, \tilde{Z}_{(2)}, \ldots, \tilde{Z}_{(n)}$.

$$\tilde{Z}^{(k)} = \begin{bmatrix} 0 & \tilde{Z}_{12}^{(k)} & \tilde{Z}_{1n}^{(k)} \\ \tilde{Z}_{21}^{(k)} & 0 & \tilde{Z}_{2n}^{(k)} \\ \vdots & \vdots & \vdots \\ \tilde{Z}_{n1}^{(k)} & \tilde{Z}_{n2}^{(k)} & 0 \end{bmatrix} \quad k = 1, 2, \ldots, p, \tag{5}$$

where k is number of experts and $\tilde{Z}_{ij}^{(k)} = \left(l_{ij}^{(k)}, m_{ij}^{(k)}, u_{ij}^{(k)}\right)$.

Step 1.2 To obtain the normalized direct-relation fuzzy matrix, the values of $\tilde{\alpha}_i^{(k)}$ and $\beta^{(k)}$ are gained by Equations 6 and 7 in triangular fuzzy numbers format to transform the linear scale into comparable scales.

$$\tilde{\alpha}_i^{(k)} = \sum \tilde{Z}_{ij}^{(k)} = \left(\sum_{j=1}^{n} l_{ij}^{(k)}, \sum_{j=1}^{n} m_{ij}^{(k)}, \sum_{j=1}^{n} u_{ij}^{(k)}\right), \tag{6}$$

$$\beta^{(k)} = \max\left(\sum_{j=1}^{n} u_{ij}^{(k)}\right) \qquad 1 \le i \le n. \tag{7}$$

Next, the normalized direct-relation fuzzy matrix ($\tilde{X}^{(k)}$) is obtained by Equation 8.

$$\tilde{X}^{(k)} = \begin{bmatrix} \tilde{X}_{11}^{(k)} & \tilde{X}_{12}^{(k)} & \tilde{X}_{1n}^{(k)} \\ \tilde{X}_{21}^{(k)} & \tilde{X}_{22}^{(k)} & \tilde{X}_{2n}^{(k)} \\ \vdots & \vdots & \vdots \\ \tilde{X}_{n1}^{(k)} & \tilde{X}_{n2}^{(k)} & \tilde{X}_{nn}^{(k)} \end{bmatrix}; \ k = 1, 2, \ldots, p, \tag{8}$$

where $\tilde{X}_{ij}^{(k)} = \left(\tilde{Z}_{ij}^{(k)} / \beta^{(k)}\right) = \left(\left(l_{ij}^{(k)} / \beta^{(k)}\right), \left(m_{ij}^{(k)} / \beta^{(k)}\right), \left(u_{ij}^{(k)} / \beta^{(k)}\right)\right)$.

Suppose there exists at least one i such that $\sum_{j=1}^{n} u_i^{(k)} < \beta^{(k)}$. Use Equations 9 and 10 to identify the average matrix ($\tilde{X}$), i.e.,

$$\tilde{X} = \frac{\left(\tilde{x}^{(1)} \oplus \tilde{x}^{(2)} \oplus \ldots \oplus \tilde{x}^{(p)}\right)}{P}, \tag{9}$$

$$\tilde{X}^{(k)} = \begin{bmatrix} \tilde{X}_{11} & \tilde{X}_{12} & \tilde{X}_{1n} \\ \tilde{X}_{21} & \tilde{X}_{22} & \tilde{X}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{X}_{n1} & \tilde{X}_{n2} & \tilde{X}_{nn} \end{bmatrix}, \tag{10}$$

where $\tilde{X}_{ij} = \left(\sum_{k=1}^{p} \tilde{x}_{ij}^{(k)} / P\right)$.

Step 1.3 The total-relation matrix $\tilde{T}$ is computed by using the normalized direct-relation $\tilde{X}^{(k)}$. It should be guaranteed about the convergence of $\lim_{w \to \infty} \tilde{X}^{W} = 0$. Finally, the total-relation fuzzy matrix is calculated using Equations 11–13.

$$\tilde{T} = \lim_{W \to \infty} \left(\tilde{X}^{1} + \tilde{X}^{2} + \ldots + \tilde{X}^{W}\right), \tag{11}$$

$$\tilde{T} = \begin{bmatrix} \tilde{t}_{11} & \tilde{t}_{12} & \tilde{t}_{1n} \\ \tilde{t}_{21} & \tilde{t}_{22} & \tilde{t}_{2n} \\ \vdots & \vdots & \vdots \\ \tilde{t}_{n1} & \tilde{t}_{n2} & \tilde{t}_{nn} \end{bmatrix}, \tag{12}$$

where $\tilde{t}_{ij} = \left(l_{ij}'', m_{ij}'', u_{ij}''\right)$.

$$\begin{aligned} \text{Matrix} \left[l_{ij}''\right] &= X_l \times (I - X_l)^{-1}, \\ \text{Matrix} \left[m_{ij}''\right] &= X_m \times (I - X_m)^{-1}, \\ \text{Matrix} \left[u_{ij}''\right] &= X_u \times (I - X_u)^{-1}. \end{aligned} \tag{13}$$

Step 1.4 To generate the cause and effect diagram, the vector $\tilde{D}_i$ and vector $\tilde{R}_i$ are calculated by the row sums and column sums, respectively.

The importance of criteria is calculated by $\widetilde{D}_i$ plus $\widetilde{R}_i$ $\left(\widetilde{D}_i+\widetilde{R}_i\right)$, which called "prominence" and shows on the horizontal axis vector of the cause and effect diagram. Notwithstanding, $\widetilde{D}_i$ minus $\widetilde{R}_i$ $\left(\widetilde{D}_i-\widetilde{R}_i\right)$ entitled "relation" indicates cause and effect of criteria on the vertical axis in such a way that if a criterion is above the horizontal axis ("relation" be positive), it is cause. Otherwise, below the horizontal axis and "relation" be negative, it is effect. Then, $\left(\widetilde{D}_i+\widetilde{R}_i\right)$ and $\left(\widetilde{D}_i-\widetilde{R}_i\right)$ are defuzzified by Equation (14).

$$\left(\widetilde{D}_i+\widetilde{R}_i,\widetilde{D}_i-\widetilde{R}_i\right)^{\text{def}}=\frac{\left(u''_{ij}-l''_{ij}\right)+\left(m''_{ij}-l''_{ij}\right)}{3}+l''_{ij}. \tag{14}$$

Finally, drawing the dataset of $\left(\widetilde{D}_i+\widetilde{R}_i,\widetilde{D}_i-\widetilde{R}_i\right)^{\text{def}}$, the cause and effect diagram is obtained.

Step 2: In the previous step, the fuzzy DEMATEL was applied to compute the relation among the main criteria. It is clear that in each problem, there are several specific subcriteria. Indeed, in the fuzzy DEMATEL-ANP method, the output of fuzzy DEMATEL is the input of fuzzy ANP, and also fuzzy ANP regarding the proposed problem needs a super matrix including main criteria, subcriteria, alternatives, and etc. which might make computations so complex. Moreover, many criteria are so close to each other in terms of content and practice. In other words, they overlap each other. Hence, it would be better to reduce the number of determined subcriteria. To obtain this matter, criteria should be ranked and eliminate some of them regarding experts' opinions. Also, in an interview, experts should be asked to consider the overlaps of criteria. In order to rank criteria based on their importance, the expert judgment method is utilized. This method was provided by Kendall (1970), and its steps are as follows:

Step 2.1: The values of t_{ik} are achieved by asking the experts for statistical operating. Equation 15 uses for computing the average criteria value $\bar{t}_i$.

$$\bar{t}_i=\frac{\sum_{k=1}^{r}t_{ik}}{r}, \tag{15}$$

where t_{ik} is the ranking of the i criteria with the k expert and r is the number of experts.

Step 2.2: To compute the weights of criteria, the mean of each criterion should divide into the total of the criteria priority values (t_i) by utilizing Equation 16.

$$q_i=\frac{\bar{t}_i}{\sum_{i=1}^{n}t_i}, \tag{16}$$

where $\sum_{i=1}^{n}q_i=1$. In other words, the sum of weights of criteria should be identical to one.

The criteria are ranked based on the gained weights, in such a way that the fewer weight, the more rank due to the fact that a criterion with the high weights means that it has the lowest rank among the experts' opinions.

Step 2.3: In this step, two values should be computed. First, the dispersion of expert ranking is calculated by Equation 17, and then the variation of the gained values is identified by using Equation 18.

$$\sigma^2=\frac{1}{r-1}\sum_{k=1}^{r}\left(t_{ik}-\bar{t}_i\right)^2, \tag{17}$$

$$\beta_i=\frac{\sigma}{\bar{t}_i}. \tag{18}$$

Step 2.4: To validate the method and the data, the compatibility of expert judgment should be calculated by several computations. Firstly, by defining the extent to the proximity of each opinion, the correlation coefficient (W) of the experts' opinions will be achieved by using Equation 19.

$$W=\frac{12S}{r^2\left(n^3-n\right)-r\sum_{k=1}^{n}T_k},\quad W\in[0;1], \tag{19}$$

where r and n are the numbers of experts and the number of criteria respectively. T_k is the set of reiterated ranks in the r rank. The total square ranking deviation is S which is obtained by Equation 20.

$$S=\sum_{i=1}^{n}\left[\sum_{k=1}^{r}t_{ik}-\frac{1}{n}\sum_{i=1}^{n}\sum_{k=1}^{r}t_{ik}\right]^2. \tag{20}$$

The value of W is computed stochastically. Hence, the importance of the concordance coefficient should be gained. If $n>7$, a distribution ought to be determined by the experts with the degrees of freedom $v=n-1$ (Kendall, 1970).

Step 2.5: Compute X^2 by Equation 21.

$$x^2_{a,v}=W.r(n-1)=\frac{12S}{r.n(n+1)-\frac{1}{n-1}\sum_{k=1}^{r}T_k}. \tag{21}$$

Step 2.6: Kendall (1970) proved that if the achieved value X^2 is greater than the critical tabular value x^2_{tbl} with a preselected confidence interval (e.g., $\alpha=0.05$), the hypothesis is not rejected about the concordance of independent experts' opinions. Further, the importance of the concordance coefficient is at the α level, if $x^2_{tbl}<x^2_{a,v}$. Thus, the compatibility of experts' ideas is satisfied, and the criteria ranking is accepted.

Step 3: The relations among the main criteria were identified by fuzzy DEMATEL which is the input of the fuzzy ANP method. In fact, ANP is the general format of AHP because it considers complex interdependencies among both of determined criteria and decision levels (main criteria, subcriteria, alternatives, and goals of a problem), which was proposed by Saaty (1996). The pairwise comparison matrix is structured by calculating the geometric mean of experts' ideas about the importance of the main criteria and subcriteria according to linguistic terms and fuzzy scales in Table 3. In the real-world decision problems, interrelations and intrarelations exist respectively among the main criteria and also subcriteria of a main criterion. It results in difficulty in problems due to relations among all subcriteria. Consequently, it is supposed that the interdependences of subcriteria are identical with their main criteria. The steps of fuzzy ANP are as follows:

Step 3.1: Structuring the pairwise comparisons matrix by carrying out the geometric mean of the engaged experts' judgments based on fuzzy scales in Table 3. $\tilde{a}_{ij}^{(k)}$ is the relative significance of element i compared to element j by asking expert k. $\tilde{A}$ is an assumed fuzzy number.

$$\tilde{A} = [\tilde{a}_{ij}]_{n\times n}, \tag{22}$$

where $\tilde{a}_{ij} = (l_{ij}, m_{ij}, u_{ij})$.

While

$$\begin{aligned} m_{ij} &= \left(\prod_{k=1}^{k} m_{ij}{}^{(k)}\right)^{\frac{1}{n}}, \\ u_{ij} &= \left(\prod_{k=1}^{k} u_{ij}{}^{(k)}\right)^{\frac{1}{n}}, \\ l_{ij} &= \left(\prod_{k=1}^{k} l_{ij}{}^{(k)}\right)^{\frac{1}{n}}. \end{aligned} \tag{23}$$

Step 3.2: Computing priority the crisp weights (values) of the main criteria. To obtain these weights, the extent analysis method developed is used as proposed by Chang (1996). Since this method is so explainable and easy in terms of mathematical operations, it is very appropriate for problems in fuzzy environments. The combined extent analysis method and fuzzy ANP was provided by Mavi and Standing (2018).

3.2 (i): Compute the value of fuzzy synthetic extent for $i = 1,2,\ldots,n$ by Equation 24.

$$\tilde{S}_i = (l_i, m_i, u_i) = \left(\sum_{j=1}^{n} \tilde{a}_{ij}\right) \otimes \left(\sum_{i=1}^{n}\sum_{j=1}^{n} \tilde{a}_{ij}\right)^{-1}. \tag{24}$$

3.2 (ii): According to Chang (1996), the possibility degree of $\tilde{S}_i = (l_i, m_i, u_i) \geq \tilde{S}_j = (l_j, m_j, u_j)$ is described by Equation 25.

$$V\left(\tilde{S}_i \geq \tilde{S}_j\right) = \begin{cases} 1 & \text{if } m_i \geq m_j, \\ 0 & \text{if } l_j \geq u_i, \\ \dfrac{l_j - u_i}{(m_i - u_i) - (m_j - l_j)} & \text{otherwise}. \end{cases} \tag{25}$$

3.2 (iii): The possibility degree for a convex fuzzy number to be greater than all the other n convex fuzzy numbers $\tilde{S}_j (j = 1,2,\ldots n; j \neq i)$ as non-normalized weights are described by Equation 26.

$$d\left(\tilde{S}_j\right) = min_j\, V\left(\tilde{S}_i \geq \tilde{S}_j\right), \tag{26}$$

where $j = 1,2,\ldots n; j \neq i$.

3.3 (iiii): The normal weights are computed by Equation 27

$$W_i = \frac{d\left(\tilde{S}_j\right)}{\sum_{i=1}^{n} d\left(\tilde{S}_j\right)}. \tag{27}$$

Step 3.3: The unweighted super matrix is structured after calculating the normal weights for all main criteria and subcriteria. This super matrix is a multiple-block matrix while each block is related to the relationship between two nodes. It should be stressed that if there is not any relation (influence) between two elements, the related weight between them is zero. The weighted super matrix is gained after normalizing the unweighted super matrix. The feature of the weighted super matrix is that the total of elements in each column is one. In the final step, the weighted super matrix should be exponentiation by 2 K + 1. K is a supposed large number. Once the weighted super matrix is fixed (or small alterations) by sequent powers, the limit super matrix is obtained and the relative weights can be identified.

Step 4: The COPRAS was introduced by Zavadskas et al. (1994) to select the best alternative among several alternatives. The fuzzy COPRAS was developed by Turanoglu Bekar et al. (2016) and Zarbakhshnia et al. (2018). The steps of the fuzzy COPRAS are as follows:

Step 4.1: fuzzy decision matrix using triangular fuzzy numbers in Table 3 is organized by Equation 28.

$$\tilde{X} = \begin{bmatrix} \left(x_{11}^l, x_{11}^m, x_{11}^u\right) & \left(x_{12}^l, x_{12}^m, x_{12}^u\right)\ldots & \left(x_{1n}^l, x_{1n}^m, x_{1n}^u\right) \\ \ldots & \ldots & \ldots \\ \ldots & \ldots & \ldots \\ \left(x_{m1}^l, x_{m1}^m, x_{m1}^u\right) & \left(x_{m2}^l, x_{m2}^m, x_{m2}^u\right)\ldots & \left(x_{mn}^l, x_{mn}^m, x_{mn}^u\right) \end{bmatrix}, \tag{28}$$

where m and n are the number of alternatives and the number of subcriteria, respectively. The performance of alternative h in subcriteria j is indicated by x_{mn}.

Step 4.2: The normalized fuzzy decision matrix is obtained by Equations 29–31.

As $\tilde{s}_{hj} = \left(s^l_{hj}, s^m_{hj}, s^u_{hj}\right)$ and $\forall hj$:

$$s^l_{hj} = x^l_{hj} / \sqrt{\sum_{h=1}^{m}\left[\left(x^l_{hj}\right)^2 + \left(x^m_{hj}\right)^2 + \left(x^u_{hj}\right)^2\right]}, \tag{29}$$

$$s^m_{hj} = x^m_{hj} / \sqrt{\sum_{h=1}^{m}\left[\left(x^l_{hj}\right)^2 + \left(x^m_{hj}\right)^2 + \left(x^u_{hj}\right)^2\right]}, \tag{30}$$

$$s^u_{hj} = x^l_{hj} / \sqrt{\sum_{h=1}^{m}\left[\left(x^l_{hj}\right)^2 + \left(x^m_{hj}\right)^2 + \left(x^u_{hj}\right)^2\right]}. \tag{31}$$

Step 4.3: The weighted normalized fuzzy decision matrix is gained by multiplying the obtained fuzzy weights by fuzzy ANP to the normalized fuzzy decision matrix.

Step 4.4: The summation of criteria is calculated where the high value of them are preference for each alternative (benefit criteria) by Equation 32.

$$\tilde{P}_j = \sum_{j=1}^{m} \tilde{x}_{hj} \quad . \tag{32}$$

Step 4.5: The summation of criteria is calculated where the low value of them are preference for each alternative (cost criteria) by Equation 33.

$$\tilde{R}_j = \sum_{j=k+1}^{m} \tilde{x}_{hj}. \tag{33}$$

Step 4.6: Determining the low value of $\tilde{R}_j$ as $\tilde{R}_{\min}$:

$$\tilde{R}_{\min} = \min_j \tilde{R}_j;\ j = 1,2,\ldots,n. \tag{34}$$

Step 4.7: The relative significance of each alternative is computed by Equation 35.

$$\tilde{Q}_j = \tilde{P}_j + \frac{\tilde{R}_{\min}\sum_{j=1}^{n}\tilde{R}_j}{\tilde{R}_j\sum_{j=1}^{n}\frac{\tilde{R}_{\min}}{\tilde{R}_j}}\ ;j = 1,2,\ldots,n. \tag{35}$$

Step 4.8: The obtained $\tilde{Q}_j$ in the previous step (4.7) is altered to non-fuzzy by Equation 36.

$$x_{hj} = \frac{\left(x^u_{hj} - x^l_{hj}\right) + \left(x^m_{hj} - x^l_{hj}\right)}{3} + x^l_{hj}. \tag{36}$$

Step 4.9: The appropriate alternative is selected by Equation 37 while the maximum weight is desired.

$$K = \max_j Q_j;\ \ j = 1,2,\ldots,n. \tag{37}$$

Step 4.10: The percentage of desired of each alternative is calculated by Equation 38:

$$N_j = \frac{Q_j}{Q_{\max}} \times 100\%\ ;j = 1,2,\ldots,n, \tag{38}$$

where Q_j is the non-fuzzy relative significance of each alternative and $Q_{\max}$ is the value of the optimum alternative. Regarding N_j the alternatives are sorted while the more value N_j is achieved, the better ranked alternatives are obtained.

3.3 | Sensitivity analysis

After solving a decision-making problem by MADM approaches, a sensitivity analysis is useful to check the robustness of the applied method due to the uncertainty and inherent instability. The sensitivity analysis process is commonly utilized to guarantee that solutions are consistent and robust. According to a set of assumptions, sensitivity analysis measures how an independent variable affects a given dependent variable. By examining ranking changes and parameters setting of criteria, this goal is accomplished. A weight setting method is used to determine whether the results will remain stable with changes in ranking order. The weight of one criterion or a specific set of criteria is altered and the weight of the other criteria is remained fix amount. In the real world, data are constantly changing, which is why sensitivity analysis is usually performed after solving a decision-making problem. It approach also so helpful to discuss the results and suggested model. Because by just applying a set of data (a case study), the consistency of the both suggested decision-making model and results cannot be fully tested. A model can have a specific and valid behavior with a set of data, but it would be different with any other data. So, this matter only can be examined by using a sensitivity analysis in which changes in results would be monitored by changing in input data.

There are a number of upsides to using sensitivity analysis presents managers and decision makers. First, its main purpose is to offer a comprehensive analysis of all variables. These predictions are likely to be more reliable due to the sensitivity analysis's in-depth nature. Second, it provides decision makers with the opportunity to identify further development opportunities. Third, through this, companies, the economy, and their investments can be analyzed to make informed decisions. Eventually, it helps decision makers to find out the milestones in their businesses for improvements or consolidations.

This technique is organized by alterations in weights of the considered criteria. The decision-making model is sensitivity if the ranks of the alternatives be changed; otherwise, it is robust. Here, five scenarios are created as follows:

Scenario 1: The weight of each criterion is placed by 1 as the peak of weight value. The original weights are determined for the rest of the criteria. This process is done for all of the criteria one by one. The scenario leads to 12 experiments.

Scenario 2: The weights of all the criteria are placed by 1 as the peak of weight value. One by one, the original weights are used for the criteria. The scenario leads to 12 experiments.

Scenario 3: The weights of all the criteria are placed by zero. One by one, the weight value 1 is used for the criteria. The scenario leads to 12 experiments.

Scenario 4: For all the criteria, random weights are generated. Yet, the summation of criteria weights should be equal to 1. The scenario leads to an experiment.

Scenario 5: Subtracting all the original criteria weights from 1. The scenario leads to an experiment.

Scenario 6: All in all, 38 experiments are designed to check the sensitivity of the decision-making model. Also, because of normalization in the criteria weighting method, all the changed criteria weights should be between one and zero.

4 | CASE STUDY AND RESULTS

4.1 | Case study

The case study of this research is a household appliance manufacturer SAMSUM in Safadasht Industrial City in Iran. SAMSUM produces durable goods, components, and consumer electronics and provides after-sale care. Some typical products made include meat grinders, vacuum cleaners, and juicers (see Figure 4). SAMSUM has received ISO 10004, ISO 10002, ISO 14001, and ISO 9001 certificates for management systems to ensure and enhance the quality of its products in compliance with international standards.

As they have assembled products, in the previous year because of a lack of material and parts, the company's managers decided to run reverse logistics activities for their company to structure a closed-loop supply chain in order to supply their company with recovered parts. However, after a thorough evaluation, they have found out the best scenario is outsourcing both reverse and forward logistics activities to a 3PLSP. Since these tasks are in its first steps in Iran, a number of 3PLSPs are few and only five 3PLSPs are candidates as alternatives to evaluate this problem. Eighteen experts engaged in a meeting for data collection to evaluate the upsides and downsides of 3PLSPs and also determine a set of criteria. Then, they have filled out questionnaires considering and regarding 3PLSPs and the proposed criteria. After receiving the questionnaires and data, the model is ready to solve in order to rank the 3PLSPs with respect to the experts' ideas and determined criteria to find the best available 3PLSPs. Based on the case study of this research, a set of criteria including sustainable, risk, and technical dimensions are considered which are evaluated by an analytical multi-step fuzzy decision-making model that consists of some MADM techniques.

FIGURE 4 Main products of SAMSUM: Vacuum cleaner (a), juicer (b), and meat grinder (c)

4.2 | Results

In this section, the obtained results after applying the decision-making model to the proposed case study are represented. Firstly, the relations among the main criteria are calculated by fuzzy DEMATEL. Secondly, the expert judgment method is applied to reduce the number of subcriteria. Then, the results of weighting the criteria by fuzzy ANP are represented. Eventually, the ranking of the 3PLSPs is indicated which is done by the fuzzy COPRAS.

After a meeting with experts and getting their ideas concerning the relations between main criteria, the initial pairwise comparison matrix is organized regarding the completed questionnaires as the fuzzy direct relation matrix (Z) (Table 4) of fuzzy DEMATEL. In the next step, by using Equations 6–10, the fuzzy direct relation matrix (Z) is normalized to make all the main criteria comparable and without units. This matrix is entitled normalized direct fuzzy relation matrix (X) as Table 5. And finally, the decision-making matrix is structured as matrix T (total relation fuzzy matrix) as Table 6. In order to calculate this matrix, Equations 11–13 are applied to the normalized direct fuzzy relation matrix (Table 5). Based on instructions in Step 1.4 and Equation 14, the cause and effect values are computed and then provided in Table 7. This information demonstrates which main criteria are cause or effect.

To better understand the data in Table 7, cause and effect diagram for the main criteria is drawn (Figure 5) using coordinates of $(D-R)$def and $(D+R)$def points where C1, C3, and C2 are the cause main criteria as they are above the $D-R$ line. C4 and C5 are effect main criteria as they are located below the $D-R$ line.

Regarding the total relations fuzzy matrix (T), the impact relationship diagram is drawn for the relation between the main criteria (see

TABLE 4 Fuzzy direct relation matrix *Z*

	C1			C2			C3			C4			C5		
Z	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
C1	0.000	0.000	0.000	0.136	0.326	0.525	0.290	0.484	0.680	0.334	0.534	0.730	0.526	0.726	0.892
C2	0.198	0.396	0.592	0.000	0.000	0.000	0.361	0.557	0.751	0.369	0.569	0.761	0.505	0.703	0.876
C3	0.040	0.157	0.353	0.051	0.326	0.375	0.000	0.000	0.000	0.451	0.646	0.805	0.438	0.638	0.832
C4	0.025	0.138	0.336	0.044	0.169	0.367	0.063	0.219	0.419	0.000	0.000	0.000	0.392	0.592	0.790
C5	0.103	0.288	0.486	0.038	0.169	0.369	0.030	0.157	0.357	0.034	0.156	0.365	0.000	0.000	0.000

TABLE 5 Normalized direct fuzzy relation matrix X

	C1			C2			C3			C4			C5		
X	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
C1	0.000	0.000	0.000	0.046	0.109	0.176	0.097	0.162	0.228	0.112	0.179	0.245	0.177	0.244	0.299
C2	0.066	0.133	0.199	0.000	0.000	0.000	0.121	0.187	0.252	0.124	0.191	0.255	0.169	0.236	0.294
C3	0.013	0.053	0.118	0.017	0.109	0.126	0.000	0.000	0.000	0.151	0.217	0.270	0.147	0.214	0.279
C4	0.008	0.046	0.113	0.015	0.057	0.123	0.021	0.073	0.141	0.000	0.000	0.000	0.132	0.199	0.265
C5	0.035	0.097	0.163	0.013	0.057	0.124	0.010	0.053	0.120	0.011	0.052	0.122	0.000	0.000	0.000

TABLE 6 Total relation fuzzy matrix T

	C1			C2			C3			C4			C5		
T	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*
C1	0.014	0.100	0.459	0.053	0.216	0.575	0.110	0.266	0.716	0.139	0.319	0.823	0.222	0.439	1.024
C2	0.078	0.250	0.648	0.011	0.250	0.448	0.136	0.329	0.762	0.157	0.381	0.864	0.226	0.502	1.062
C3	0.023	0.136	0.490	0.023	0.197	0.467	0.010	0.102	0.438	0.160	0.321	0.735	0.177	0.379	0.880
C4	0.015	0.101	0.427	0.018	0.117	0.409	0.026	0.134	0.494	0.010	0.085	0.437	0.142	0.296	0.767
C5	0.036	0.133	0.429	0.015	0.108	0.379	0.016	0.109	0.444	0.020	0.126	0.505	0.014	0.106	0.498

TABLE 7 Cause and effect values

	D			*R*			*D* − *R*			*D* + *R*			(*D* − *R*)def	(*D* + *R*)def
	l	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*l*	*m*	*u*	*D* − *R*	*D* + *R*
C1	0.54	1.34	3.60	0.17	0.72	2.45	0.37	0.62	1.15	0.71	2.06	6.05	1.23	6.50
C2	0.61	1.71	3.78	0.12	0.89	2.28	0.49	0.82	1.51	0.73	2.60	6.06	1.62	6.69
C3	0.39	1.13	3.01	0.30	0.94	2.85	0.09	0.19	0.16	0.69	2.07	5.87	0.19	6.33
C4	0.21	0.73	2.53	0.49	1.23	3.37	−0.28	−0.50	−0.83	0.70	1.97	5.90	−0.90	6.32
C5	0.10	0.58	2.26	0.78	1.72	4.23	−0.68	−1.14	−1.98	0.88	2.31	6.49	−2.13	6.96

Figure 6). Figure 6 organizes with the defuzzified of the total relations matrix with the threshold values which is set about 0.2 according to the ideas of experts.

Figure 6 illustrates the relationships among main criteria, in such a way that the shown relations are non-zero and has value but the others are all zero (are not drawn). For instance, between C4 and C5 is a two-way relation, and both relations are non-zero. Nonetheless, between C1 and C4 is a one-way relation, in a way that C4 is influenced by C1, yet C4 has not any impact on C1. Indeed, Figure 5 is the input of the fuzzy ANP method in terms of the logic of relationships.

Before applying the relationships among main criteria by fuzzy DEMATEL to the fuzzy ANP method, the number of subcriteria should be reduced to ease computational effort. For this, the expert judgment method is applied to the research to reduce almost half of the subcriteria based on the experts' opinion. Table 8 shows the

FIGURE 5 Cause and effect diagram for the main criteria

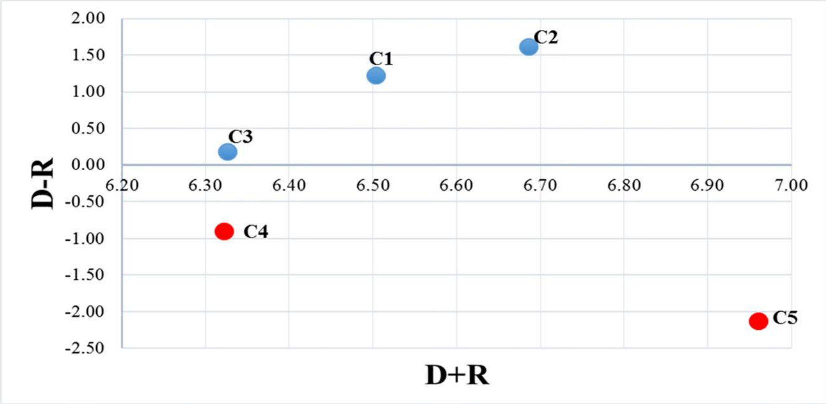
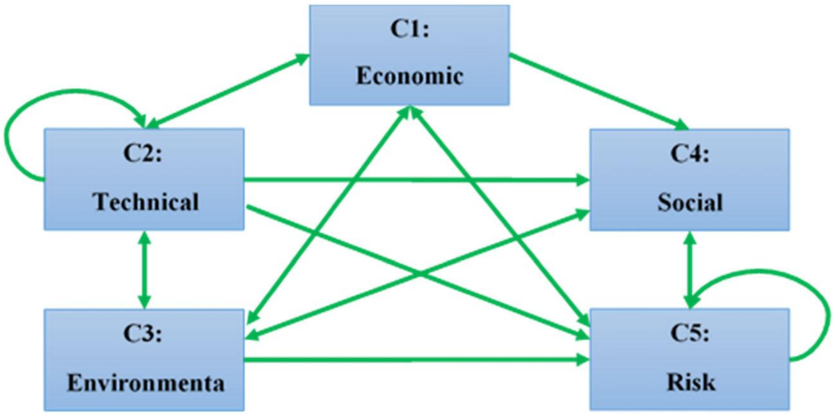


FIGURE 6 Impact relationship diagram for the relation between the main criteria



achieved values for statistical processing t_{jk} by interviewing 18 experienced experts to point (rank) about 25 subcriteria. In fact, these data are the inputs of the expert judgment method.

Summing the columns of Table 8 individually and applying them to Equation (15), the average criteria rank values of each subcriteria is found. The criteria weights are computed by Equation 16. The subcriteria are ranked by the average criteria rank value whereby a smaller average criteria rank value suggests a higher rank (Table 9).

To validate the performed algorithm, several operations should be done. In order to be satisfied the agreement of experts' opinions, first, the dispersion of expert ranking and then the variation of the achieved values should be calculated by Equations 17 and 18 respectively for each subcriteria. Next, the total square ranking deviation which is equal to 391,975 is calculated by Equation 20 to apply to Equation 19 so as to gain the correlation coefficient of the experts' opinions which is about 0.93. Finally, the value of X^2 (the importance of the concordance coefficient which is not related to ranks) is computed by Equation 21. Since $x^2_{a,v} > x^2_{tbl}$ (402.03 > 20.87), the hypothesis concerning the consent of experts in ranking is accepted.

After the ranking the subcriteria, the top 12 are selected and the rest of the subcriteria are eliminated. Table 10 presents the final 12 subcriteria with their ranks which are used for the fuzzy ANP steps.

Table 11 presents the total fuzzy pairwise comparison matrix for the main criteria based on the experts' scoring by utilizing Equation 23. Moreover, the non-normalized weights ($d(\widetilde{s}_i)$) and the normalized weights (W_i) of the main criteria are computed by Equations 24–27 which are shown in the last row of Table 11.

The main social criteria C4 has achieved the highest normalized weight 0.244 followed by risk C5, economic C1, and technical C2 (the normalized weights are 0.208, 0.191, and 0.185, respectively). However, the lowest one is main environmental criteria C3 with a 0.171 normalized weight. These operations should be done for all of the subcriteria to calculate all of the priority weights. Next, with respect to the main criteria, pairwise comparison matrices are structured to organize the unweighted super matrix (Table 12). In the next step, the unweighted super matrix should be normalized to turn into the weighted super matrix. To achieve limit super matrix, the weighted super matrix should be powered about 2 K + 1.

Once the weighted super matrix is fixed (or has small alterations) by sequent powers, the limit super matrix is obtained, and the relative weights can be identified. It should be noted that the limit super matrix is achieved after 13 powers (see Table 13). Moreover, the pink sections in Tables 12 and 13 are the pairwise comparison matrices of subcriteria which are the aims of fuzzy ANP in this research to compute the subcriteria weights. In this stage, the weights obtained by fuzzy ANP are applied to fuzzy COPRAS as inputs. Through

TABLE 8 Criteria importance level determined by the experts

Expert number $k = 1,2,\ldots,18$	Efficiency criteria rank values, $t_{jk}; j = 1,\ldots,nn = 25$																								
	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19	C 20	C 21	C 22	C 23	C 24	C 25
EX 1	1	2	13	12	21	14	3	4	22	5	6	17	16	24	15	7	25	18	8	23	9	20	10	19	11
EX 2	1	3	11	10	25	12	2	5	22	6	4	15	18	23	17	8	24	16	9	20	7	19	13	21	14
EX 3	3	1	12	13	25	11	2	4	21	7	5	15	17	23	16	6	24	18	8	22	10	19	14	20	9
EX 4	2	3	11	16	25	12	1	4	23	5	6	14	18	24	15	7	22	17	9	21	8	20	13	19	10
EX 5	1	2	13	23	22	11	4	3	21	7	6	12	20	25	14	5	24	15	8	18	10	19	16	17	9
EX 6	4	5	10	20	11	13	6	3	25	1	2	9	23	24	12	7	21	19	8	16	18	22	17	15	14
EX 7	1	2	12	17	25	13	3	5	24	6	4	16	18	23	14	7	22	15	8	19	9	21	10	20	11
EX 8	2	1	14	13	25	11	5	3	24	4	6	15	16	23	17	8	22	18	7	19	10	20	9	21	12
EX 9	1	2	16	15	24	14	3	4	25	5	6	13	17	22	12	7	23	18	8	20	9	19	10	21	11
EX 10	1	2	17	16	25	15	4	3	24	5	6	14	13	23	9	7	20	21	8	22	12	18	11	19	10
EX 11	3	1	11	12	25	13	4	5	21	6	2	15	17	23	16	8	24	18	7	22	9	19	14	20	10
EX 12	1	2	12	23	25	11	4	3	21	7	6	13	20	24	14	5	22	15	8	19	10	18	16	17	9
EX 13	1	3	13	10	22	12	2	5	25	6	4	15	18	24	17	8	23	16	9	20	7	19	11	21	14
EX 14	2	1	14	13	25	11	5	3	24	4	6	15	17	23	16	8	22	19	7	18	10	20	9	21	12
EX 15	1	3	11	12	25	10	2	5	22	6	4	15	16	23	14	8	24	18	9	20	7	19	13	21	17
EX 16	2	3	10	16	24	12	1	4	22	5	6	14	18	25	15	7	23	17	9	21	8	19	13	20	11
EX 17	1	2	13	16	25	15	4	3	24	5	6	14	17	23	9	7	20	21	8	22	10	18	11	19	12
EX 18	1	3	11	10	25	12	6	4	23	3	7	15	14	24	13	5	21	22	8	20	9	17	16	19	18

TABLE 9 Algorithm of criteria importance orders establishment

Process of calculation	Efficiency criteria $x_j; j=1,\ldots,n\ n=25$																								
	C 1	C 2	C 3	C 4	C 5	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19	C 20	C 21	C 22	C 23	C 24	C 25
Sum of ranks	29	41	224	267	424	222	61	70	413	93	92	256	313	423	255	125	406	321	146	362	172	346	226	350	214
The average criteria rank values	1.61	2.28	12.44	14.83	23.56	12.33	3.39	3.89	22.94	5.17	5.11	14.22	17.39	23.50	14.17	6.94	22.56	17.83	8.11	20.11	9.56	19.22	12.56	19.44	11.89
Criteria rank (t_j)	1	2	12	16	25	11	3	4	23	6	5	15	17	24	14	7	22	18	8	21	9	19	13	20	10
Criteria weight (q_j)	0.005	0.007	0.038	0.046	0.072	0.038	0.010	0.012	0.071	0.016	0.016	0.044	0.053	0.072	0.044	0.021	0.069	0.055	0.025	0.062	0.029	0.059	0.039	0.060	0.037
Dispersion of experts ranking values (σ^2)	0.84	1.04	3.67	16.15	11.44	2.12	2.37	0.69	2.17	2.26	2.10	3.01	4.94	0.62	5.91	1.11	2.14	4.26	0.46	3.16	6.14	1.36	6.61	2.85	6.81
Variation (β_j)	0.569	0.447	0.154	0.271	0.144	0.118	0.454	0.214	0.064	0.291	0.284	0.122	0.128	0.033	0.172	0.152	0.065	0.116	0.083	0.088	0.259	0.061	0.205	0.087	0.220
The total square ranking deviation (S)	$S=\sum_{j=1}^{n}\left[\sum_{k=1}^{r}t_{jk}-\frac{1}{n}\sum_{j=1}^{n}\sum_{k=1}^{r}t_{jk}\right]^2=(29-234)^2+(41-234)^2+(224-234)^2+(267-234)^2+(424-234)^2+(222-234)^2+(61-234)^2+(70-234)^2+(413-234)^2+(93-234)^2+(92-234)^2+(256-234)^2+(313-234)^2+(423-234)^2+(255-234)^2+(125-234)^2+(406-234)^2+(321-234)^2+(146-234)^2+(362-234)^2+(172-234)^2+(346-234)^2+(226-234)^2+(350-234)^2+(29-234)^2=391975$																								
The coefficient of concordance (W)	$W=\frac{12S}{r^2(n^3-n)-r\sum_{k=1}^{r}T_k}=\frac{12\times391975}{18^2(25^3-25)}=0.93$																								
The importance of the concordance coefficient (no related ranks) ($x^2_{a,v}$)	$x^2_{a,v}=\frac{12S}{rn(n+1)-\frac{1}{n-1}\sum_{k=1}^{r}T_k}\ \frac{12\times391975}{18\times25(26)}=402.03$																								
Rank of table concordance x^2_{tbl} when the importance equal to 1%	Degrees of freedom: $v=n-1\rightarrow25-1=24$																								
Compatibility of expert judgment (Kendall, 1970).	$x^2_{a,v}=402.03>x^2_{tbl}=20.87$—The hypothesis about the consent of experts in rankings is accepted.																								

Equations 28–31, the fuzzy decision, normalized fuzzy decision, and weighted normalized fuzzy decision matrices are found such that Table 13 is the weighted normalized fuzzy decision matrix.

In Table 14, first, the summation of criteria in which the high ($\widetilde{P}_j$) and low ($\widetilde{R}_j$) value of them are preference for each 3PLSP are gained by Equations 32 and 33. Then, the relative significance of each 3PLSP ($\widetilde{Q}_j$) is gotten by Equation 35 which is turned to non-fuzzy value by Equation 36. Finally, the percentage of desired of each 3PLSP (N_j) is computed by Equation 13. These values and ranking of 3PLSP s are reported in Table 14, which is A1 > A2 > A4 > A3 > A5 as the final ranking of the 3PLSPs.

It can be seen that 3PLSP #1 is the best 3PLSP who is most influenced by the quality of processes, respect for the local rules and policies, delivery lead time, and cost criteria. It means that the participated experts in this research noticeably focus on economic and social criteria while the other criteria are important too, such as environmental criteria. Interestingly, the criteria as quality of processes, respect for the local rules and policies, affect 3PLSP number 2 to gain the second rank the same as the 3PLSP number 1.

3PLSP #5 is the worst 3PLSP among five 3PLSPs which ranked with the proposed decision-making model. Cost, experience, problem-solving capability, IT knowledge are the criteria that have a considerable impact on selecting 3PLSP number 5 as the last one. Thereby, there is obviously a lack of attention to environmental and social issues in expert's ideas due to the fact that in both of the best and worst choices environmental criteria have at least affect that is a considerable point which decision makers should pay their attention to it. Additionally, 3PLSP number 3 is obtained the second-bottommost rank under the main action of cost, lead time, financial risk, and safety criteria on getting this rank. It should be stressed that risk criteria (operational risk) have not any impact on both sides (best and worst) of the ranking process.

It would indicate that in the opinions of the engaged experts, there is no risk in outsourcing logistics activities to the 3PLSPs. Hence, it would be another reason that can prove the advantages of outsourcing.

From the weighted normalized fuzzy decision matrix (Table 15), it is clear that experts who participated in this study concentrated on the economic and technological criteria more than other dimensions and criteria. This emphasis demonstrates that in Iranians industrial zones, the focus is still on profit and economic matters while the environmental and social issues have been missed. This is a significant point that the managers should work on it harder. According to the analysis and experts' ideas, since in this problem (selection), we have several criteria with qualitative nature and uncertainty, the suggested approach is a fuzzy one include lower, middle, and upper limit for each point that helps to not only face uncertainty, but alter qualitative criteria to quantitative criteria.

4.3 | Sensitivity analysis results

After receiving the results and ranking of the 3PLSPs, the robustness of the proposed decision-making model should be checked. In previous works which applied sensitivity analysis to MADM problems, researchers usually concentrated on determining the most sensitive attribute to investigate the minimum value of the change. Nonetheless, in the recent updates of sensitivity analysis for MADM problems, monitoring the alterations in the final results and ranking is preferred by changing in weight of a criterion or a set of criteria. For that reason, five scenarios including 38 experiments are considered. These

TABLE 10 Remaining subcriteria after the ranking based on experts opinions

Main criteria	Subcriteria	Rank
C_1: Economic	$C1_1$: Cost	1
	$C1_2$: Quality of processes	2
	$C1_3$: Experience	12
	$C1_4$: Delivery lead time	11
	$C1_5$: Services	3
C_2: Technical	$C2_1$: Problem-solving capability	4
	$C2_2$: Product recovery technology	6
	$C2_3$: IT knowledge	5
C_3: Environmental	$C3_1$: Green certifications	7
	$C3_2$: Environmental-management system	8
C_4: Social	$C4_1$: Respect for the local rules and policies	9
C_5: Risk	$C5_1$: Operational risk	10

TABLE 11 Fuzzy pairwise comparison matrix for main criteria

	C1			C2			C3			C4			C5		
C1	1	1	1	1.98	3.79	5.95	3.37	5.10	7.34	2.16	3.34	5.70	1.89	3.41	5.67
C2	1.97	2.92	5.31	1	1	1	2.82	4.62	6.85	2.38	3.44	5.78	3.66	5.71	7.61
C3	2.96	4.28	6.61	3.22	4.96	7.19	1	1	1	2.70	3.74	6.16	3.05	5.25	7.20
C4	2.45	3.32	5.82	1.50	2.14	4.09	1.50	2.54	4.82	1	1	1	1.25	1.62	3.84
C5	1.89	3.40	5.69	2.44	4.18	6.38	1.71	2.93	5.26	1.98	2.87	5.30	1	1	1
$\widetilde{s}_i$	0.094	0.212	0.439	0.105	0.220	0.451	0.116	0.240	0.476	0.071	0.141	0.348	0.084	0.187	0.411
$d(\widetilde{s}_i)$	0.783			0.756			0.701			1			0.851		
W_i	0.191			0.185			0.171			0.244			0.208		

TABLE 12 Unweighted super matrix

	Goal	C1	C2	C3	C4	C5	C11	C12	C13	C14	C15	C21	C22	C23	C31	C32	C41	C51
Goal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C1	0.180	0.034	0.134	0.162	0.112	0.058	0.000	0.000	0.000	0.000	0.000	0.042	0.011	0.100	0.185	0.134	0.006	0.139
C2	0.168	0.074	0.000	0.128	0.123	0.155	0.103	0.048	0.012	0.042	0.123	0.000	0.000	0.000	0.201	0.095	0.000	0.000
C3	0.144	0.145	0.249	0.000	0.147	0.124	0.057	0.069	0.011	0.002	0.090	0.060	0.066	0.160	0.000	0.000	0.112	0.000
C4	0.294	0.000	0.000	0.045	0.000	0.021	0.016	0.030	0.036	0.054	0.007	0.121	0.063	0.052	0.072	0.027	0.000	0.127
C5	0.213	0.084	0.000	0.000	0.091	0.053	0.072	0.044	0.073	0.049	0.159	0.002	0.031	0.024	0.044	0.032	0.140	0.000
C11	0.000	0.075	0.103	0.091	0.084	0.023	0.036	0.097	0.162	0.028	0.132	0.011	0.070	0.115	0.107	0.119	0.035	0.176
C12	0.000	0.033	0.093	0.095	0.076	0.039	0.057	0.121	0.187	0.152	0.035	0.123	0.010	0.152	0.061	0.130	0.164	0.169
C13	0.000	0.116	0.105	0.089	0.060	0.049	0.042	0.081	0.179	0.034	0.172	0.222	0.164	0.006	0.065	0.076	0.172	0.083
C14	0.000	0.085	0.020	0.113	0.078	0.074	0.079	0.021	0.073	0.141	0.245	0.111	0.114	0.101	0.011	0.109	0.061	0.008
C15	0.000	0.054	0.008	0.110	0.060	0.096	0.126	0.010	0.053	0.120	0.013	0.118	0.240	0.129	0.036	0.009	0.032	0.163
C21	0.000	0.072	0.000	0.088	0.062	0.086	0.016	0.211	0.274	0.044	0.003	0.000	0.000	0.000	0.067	0.062	0.043	0.045
C22	0.000	0.086	0.000	0.012	0.015	0.092	0.253	0.018	0.297	0.174	0.034	0.000	0.000	0.000	0.012	0.035	0.156	0.173
C23	0.000	0.095	0.000	0.005	0.031	0.063	0.243	0.339	0.019	0.233	0.062	0.000	0.000	0.000	0.016	0.049	0.054	0.125
C31	0.000	0.089	0.130	0.000	0.049	0.055	0.135	0.129	0.124	0.058	0.153	0.012	0.083	0.032	0.000	0.000	0.200	0.073
C32	0.000	0.132	0.158	0.000	0.009	0.029	0.005	0.058	0.076	0.068	0.091	0.067	0.025	0.033	0.000	0.000	0.136	0.113
C41	0.000	0.000	0.000	0.062	0.000	0.037	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.014	0.113	0.000	0.136
C51	0.000	0.101	0.000	0.000	0.002	0.007	0.035	0.049	0.003	0.034	0.168	0.000	0.000	0.000	0.000	0.000	0.406	0.036

TABLE 13 Limit super matrix

	Goal	C1	C2	C3	C4	C5	C11	C12	C13	C14	C15	C21	C22	C23	C31	C32	C41	C51
Goal	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C3	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C5	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
C11	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
C12	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095	0.095
C13	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073	0.073
C14	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065	0.065
C15	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
C21	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078	0.078
C22	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091	0.091
C23	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076
C31	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093	0.093
C32	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089	0.089
C41	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085	0.085
C51	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076	0.076

TABLE 14 Value of final results and ranking with fuzzy COPRAS

Alternative	$\widetilde{P}_j$			$\widetilde{R}_j$			$\widetilde{Q}_j$			Non-fuzzy Q_j	N_j (100%)	Rank
A1	0.1276	0.1966	0.2475	0.0331	0.0502	0.0677	0.1478	0.2382	0.3128	0.2330	100.00	1
A2	0.1048	0.1696	0.2364	0.0299	0.0514	0.0714	0.1272	0.2103	0.2984	0.2120	90.99	2
A3	0.0814	0.1419	0.2073	0.0252	0.0459	0.0671	0.1079	0.1875	0.2732	0.1895	81.36	4
A4	0.0860	0.1456	0.2155	0.0235	0.0424	0.0645	0.1145	0.1949	0.2841	0.1978	84.93	3
A5	0.0680	0.1344	0.2031	0.0198	0.0398	0.0623	0.1019	0.1869	0.2742	0.1877	80.56	5

scenarios have various input parameters (weights of criteria) for the suggested decision-making model. The achieved results based on the introduced scenarios are represented in Table 16. Additionally, for better understanding, Figure 7 illustrates the results more obvious.

From Table 16 and Figure 7, in nine of the 38 experiments, obtaining results (alternatives ranking) is not feasible because of the formulation of Equation 35 that considered being cost or benefit criterion. In other words, regarding the definition of Scenario 3, that said the weights of all the criteria are placed by zero, and then one by one the weight value 1 is used for the criteria. So, once a benefit criterion receives weight value 1, calculating the relative significance for alternatives by Equation 35 is not feasible. Therefore, from the experiments number 27–35 ranking is not feasible.

Moreover, in 11 of the 38 experiments the order of ranking is completely identical with the gained results of the case study (A1 > A2 > A4 > A3 > A5). It means that the ranking of approximately 29% of experiments is the same as the original ranking. It could validate the achieved results of the case study and the provided decision-making model. Besides, in 23 out of 38 (roughly 60%) experiments A1 is the best alternative the same as the original ranking which leads to choose and validate this one as the most appropriate alternative. Hence, A1 clearly is the winner. However, A2 and A5 are rated as the first (3 times), while A3 and A4 have never achieved the first rank. Nonetheless, in terms of the worth rank, A5 (16 times), A3 (5 times), A4 (4 times), A1 (3 times), and A2 (once) are gotten as the last rank. Overall, it can be proven that the obtained results of the suggested decision-making model are so sensitive in altering the criteria weights terms with various received results in 38 experiments.

5 | DISCUSSION

The obtained results of the current work can prepare future directions for researchers and logistics industry in Iran and also particularly for the appliance manufacturer as the case study of this study. The existed limitations which are recognized in the available decision process lead to opportunities for future research.

The first limitation of this study is about interrelations of criteria. The interdependencies among all criteria are not considered. In fact, it is done just for main criteria. The reason behind this idea is that the gained interrelations of main criteria are applied to criteria (sub-criteria) in weighting step (fuzzy ANP), so it is not reasonable to calculate all the interrelations and also increase the rate of computations. The second limitation is belonged to the theoretical side, in which feature reduction is needed due to the number of criteria that should be diminished. The expert judgment method is utilized for this purpose which is an expert based method. Third limitation is data and sample size. Given reverse operations of logistics are new field in Iran, the collected data may suffer from lack of number of experts who engaged in this study and lack of experts' experience in practice. Validate the suggested model for outsourcing both reverse and forward logistics operations to a 3PLSP in a sustainable circular economy, data, and achieved results is the final limitation in the current research. The carried out sensitivity analysis can prove all the aspects of the research since diversity of proposed scenarios tests all of them.

In light of the gained results, it is significant to investigate the interdependencies between considered main criteria. Regarding fuzzy DEMATEL outcomes, they have influence on each other, based on Tables 3–7 and Figures 5 and 6. The economic, technical, and environmental are the cause, and they can influence effect main criteria as social and risk main criteria. The effect main criteria are influenced by causes. The indicated interrelations can be visibly illustrated as a structural model in Figure 5 to make them easier for interpreting for practical managers. As an illustration, they should consider interrelations between environmental and technical criteria, if there is a need for reaction to technical criteria.

Tran and Do (2021) identified the "cost" as the most significant criteria in logistics operation outsourcing to third-party providers in a sustainable circular economy, the results of the paper also indicate cost as the important criteria in this decision problem. There are some other important criteria which influence selection of a qualified service provider, however, as Aguezzoul (2014) mentioned 'quality' and 'services' as other important criteria. In our study, above criteria are also identified based on ideas of experts in weighting step in Tables 9 and 13. This comparison might help decision maker to rely first considered criteria and second engaged experts' ideas in scoring both criteria and 3PLSPs.

In selecting the decision-making technique, the majority of weighting techniques like AHP, criteria weights are calculated in hierarchical structure. Nonetheless, many of the real world criteria have internal and external relations/dependencies/interactions in the set of considered criteria for a decision process. Hence, ANP handles the priority and preference of criteria in 3PLSP selection using pairwise comparison matrix in which the input data are both fuzzy DEMATEL outputs (interrelations of criteria) and experts' scores. All in all, combination of fuzzy DEMATEL-ANP can handle criteria preferences

TABLE 15 Weighted normalized fuzzy decision matrix between alternatives and criteria

Alternative	Cost			Quality of processes			Experience			Delivery lead time			Services			Problem-solving capability		
A1	0.0093	0.0136	0.0220	0.0162	0.0254	0.0316	0.0119	0.0175	0.0226	0.0095	0.0149	0.0202	0.0154	0.0238	0.0292	0.0138	0.0200	0.0250
A2	0.0110	0.0203	0.0288	0.0116	0.0193	0.0285	0.0125	0.0188	0.0238	0.0083	0.0149	0.0214	0.0077	0.0138	0.0223	0.0144	0.0219	0.0269
A3	0.0119	0.0203	0.0288	0.0085	0.0162	0.0247	0.0056	0.0107	0.0175	0.0065	0.0125	0.0185	0.0115	0.0200	0.0277	0.0056	0.0119	0.0181
A4	0.0076	0.0144	0.0237	0.0093	0.0185	0.0270	0.0069	0.0119	0.0182	0.0065	0.0125	0.0191	0.0069	0.0115	0.0200	0.0113	0.0181	0.0250
A5	0.0119	0.0203	0.0288	0.0131	0.0224	0.0293	0.0063	0.0119	0.0188	0.0036	0.0089	0.0155	0.0069	0.0131	0.0208	0.0044	0.0106	0.0175
	Product recovery technology			**IT knowledge**			**Green certifications**			**Environmental-management system**			**Respect for the local rules and policies**			**Operational risk**		
A1	0.0136	0.0200	0.0264	0.0135	0.0212	0.0257	0.0094	0.0181	0.0267	0.0152	0.0232	0.0280	0.0187	0.0273	0.0323	0.0143	0.0217	0.0255
A2	0.0152	0.0224	0.0296	0.0128	0.0199	0.0257	0.0118	0.0189	0.0267	0.0080	0.0160	0.0256	0.0108	0.0187	0.0273	0.0106	0.0161	0.0211
A3	0.0056	0.0112	0.0200	0.0096	0.0141	0.0199	0.0126	0.0212	0.0283	0.0144	0.0216	0.0288	0.0079	0.0151	0.0222	0.0068	0.0130	0.0199
A4	0.0104	0.0184	0.0280	0.0090	0.0148	0.0212	0.0126	0.0220	0.0306	0.0104	0.0160	0.0240	0.0093	0.0143	0.0215	0.0093	0.0155	0.0217
A5	0.0128	0.0216	0.0296	0.0032	0.0090	0.0167	0.0079	0.0165	0.0244	0.0056	0.0136	0.0224	0.0079	0.0158	0.0237	0.0043	0.0106	0.0180

TABLE 16 Sensitivity analysis results

Scenario	Experiment	Criteria weights	N_j (100%) A 1	A 2	A 3	A 4	A 5	Alternative ranking
1	1	$W_{c1} = 1, W_{c2-12} =$ original weights	100	83.62	78.00	91.97	77.16	A1 > A3 > A4 > A2 > A5
	2	$W_{c2} = 1, W_{c1,\ c3-12} =$ original weights	100	86.02	74.37	79.84	84.49	A1 > A2 > A5 > A4 > A3
	3	$W_{c3} = 1, W_{c1-2,\ c4-12} =$ original weights	100	98.29	73.44	78.20	75.95	A1 > A2 > A5 > A3 > A4
	4	$W_{c4} = 1, W_{c1-3,\ c5-12} =$ original weights	88.97	83.82	85.39	86.60	100	A2 > A5 > A4 > A3 > A1
	5	$W_{c5} = 1, W_{c1-4,\ c6-12} =$ original weights	100	77.16	84.01	70.17	69.78	A1 > A3 > A2 > A4 > A5
	6	$W_{c6} = 1, W_{c1-5,\ c7-12} =$ original weights	100	99.19	71.03	88.73	67.97	A1 > A2 > A4 > A3 > A5
	7	$W_{c7} = 1, W_{c1-6,\ c8-12} =$ original weights	99.31	100	71.62	88.81	91.98	A2 > A1 > A5 > A4 > A3
	8	$W_{c8} = 1, W_{c1-7,\ c9-12} =$ original weights	100	93.86	76.83	79.48	63.57	A1 > A2 > A4 > A3 > A5
	9	$W_{c9} = 1, W_{c1-8,\ c10-12} =$ original weights	99.80	97.07	95.68	100	84.24	A2 > A3 > A4 > A1 > A5
	10	$W_{c10} = 1, W_{c1-9,\ 11-12} =$ original weights	100	82.78	89.54	80.39	71.51	A1 > A3 > A2 > A4 > A5
	11	$W_{c11} = 1, W_{c1-10,\ c12} =$ original weights	100	80.70	68.53	69.97	69.42	A1 > A2 > A5 > A3 > A4
	12	$W_{c12} = 1, W_{c1-11} =$ original weights	83.21	86.94	89.74	84.53	100	A5 > A3 > A2 > A4 > A1
2	13	$W_{c1} =$ original weights, $W_{c2-12} = 1$	100	91.81	81.45	82.83	81.72	A1 > A2 > A4 > A5 > A3
	14	$W_{c2} =$ original weights, $W_{c1,\ c3-12} = 1$	100	92.15	83.00	86.12	79.64	A1 > A2 > A4 > A3 > A5
	15	$W_{c3} =$ original weights, $W_{c1-2,\ c4-12} = 1$	100	89.78	82.67	86.04	81.32	A1 > A2 > A4 > A3 > A5
	16	$W_{c4} =$ original weights, $W_{c1-3,\ c5-12} = 1$	100	90.58	79.53	83.39	76.91	A1 > A2 > A4 > A3 > A5
	17	$W_{c5} =$ original weights, $W_{c1-4,\ c6-12} = 1$	100	93.91	80.80	88.05	82.84	A1 > A2 > A5 > A3 > A4
	18	$W_{c6} =$ original weights, $W_{c1-5,\ c7-12} = 1$	100	89.48	83.26	84.23	82.88	A1 > A2 > A4 > A3 > A5
	19	$W_{c7} =$ original weights, $W_{c1-6,\ c8-12} = 1$	100	89.01	83.24	84.01	78.10	A1 > A2 > A5 > A3 > A4
	20	$W_{c8} =$ original weights, $W_{c1-7,\ c9-12} = 1$	100	90.44	82.21	85.91	83.64	A1 > A2 > A4 > A3 > A5
	21	$W_{c9} =$ original weights, $W_{c1-8,\ c10-12} = 1$	100	89.74	78.57	81.95	79.78	A1 > A2 > A4 > A5 > A3
	22	$W_{c10} =$ original weights, $W_{c1-9,\ c11-12} = 1$	100	92.70	79.65	85.87	82.44	A1 > A2 > A4 > A5 > A3
	23	$W_{c11} =$ original weights, $W_{c1-10,\ c12} = 1$	100	93.32	84.33	88.34	83.08	A1 > A2 > A4 > A3 > A5
	24	$W_{c12} =$ original weights, $W_{c1-11} = 1$	100	88.74	77.52	82.32	75.19	A1 > A2 > A4 > A3 > A5
3	25	$W_{c1} = 1, W_{c2-12} = 0$	100	74.46	73.43	98.33	73.43	A1 > A4 > A2 > A3 = A5
	26	$W_{c2} = 1, W_{c1,\ c3-12} = 0$	62.07	61.43	73.02	71.87	100	A5 > A3 > A4 > A1 > A2
	27	$W_{c3} = 1, W_{c1-2,\ c4-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	28	$W_{c4} = 1, W_{c1-3,\ c5-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	29	$W_{c5} = 1, W_{c1-4,\ c6-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	30	$W_{c6} = 1, W_{c1-5,\ c7-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	31	$W_{c7} = 1, W_{c1-6,\ c8-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	32	$W_{c8} = 1, W_{c1-7,\ c9-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	33	$W_{c9} = 1, W_{c1-8,\ c10-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	34	$W_{c10} = 1, W_{c1-9,\ c11-12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	35	$W_{c11} = 1, W_{c1-10,\ c12} = 0$	0.00	0.00	0.00	0.00	0.00	Not feasible
	36	$W_{c12} = 1, W_{c1-11} = 0$	52.70	67.04	80.32	68.39	100.0	A5 > A3 > A4 > A2 > A1
4	37	C1 = 0.08, C2 = 0.05, C3 = 0.2, C4 = 0.07, C5 = 0.01, C6 = 0.06, C7 = 0.02, C8 = 0.1, C9 = 0.04, C10 = 0.2, C11 = 0.07, C12 = 0.1	100	92.73	83.20	83.56	78.44	A1 > A2 > A4 > A3 > A5
5	38	All the original criteria weights subtract from 1.	100	91.78	81.89	85.19	81.52	A1 > A2 > A4 > A3 > A5

considering main criteria interdependencies. In addition to this, the fuzzy COPRAS that is employed to rank 3PLSPs. The importance and utility degree of 3PLSPs are determined with a stepwise sorting operator in the COPRAS method. Aghdaie et al. (2012) stated this technique admits the consideration of maximizing and minimizing criteria to carry out COPRAS of 3PLSPs.

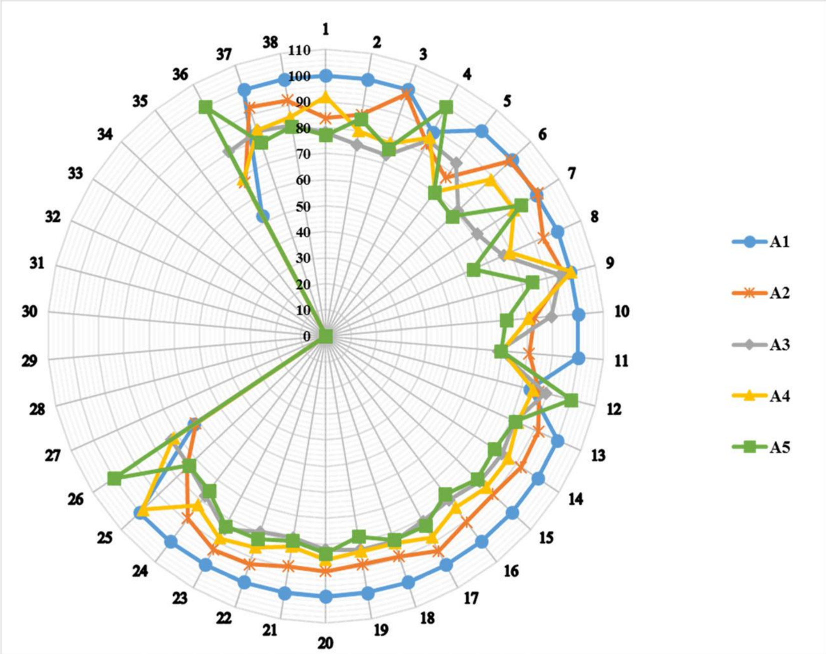


FIGURE 7 Results of sensitivity analysis are demonstrated in a radar chart

6 | MANAGERIAL, POLICY, AND THEORETICAL IMPLICATIONS

There are some implications of this study in managerial, policy, and theoretical views. The application and case study of this paper are the key managerial implication as a household appliance manufacturing company. The model is solved and validated based on the experts' opinions of the mentioned company. Regardless of researchers, the obtained results of this study might use for decision makers and managers of companies that produce assembled products. Indeed, there are two sides to the implication of this study. The first one is motivating to move to the side of circular economy and subsequently sustainable development which lead to run reverse logistics network. The second one is using 3PLSPs for logistics activities of manufacturers (outsourcing). On both sides, there are many upsides for goods producers and managers. The most significant advantage is profit and economic benefits in such a way that by utilizing both reverse logistics and outsourcing strategies, the costs are reduced and accordingly profits are increased. Thus, it would be a rewarding role model for encouraging other companies' managers in order to focus on new strategies such as circular economy and reverse logistics which can be a cause of protecting the environment. Also, outsourcing is the cause of not only decreasing the responsibility of companies to governments and regulatory agencies, but maximizing the quality of products, because 3PLSPs have professional teams for carrying out the logistics operations.

From the results of this research, the organizations which are related to economic, environmental, and social issues can persuade government to legislate powerful laws to enforce manufacturers to focus on sustainable development more than before with using circular economy and reverse logistics operations and strategies like that.

The circular economy sets out to redefine development by emphasizing positive comprehensive upsides instead of the current take–make–waste extractive industrial model. It will occur if attempts would be done to separate economic activity from the existed limited consumption resources and to eliminate waste in the system. So, policymakers need to establish and legislate some policies and rules to guarantee the implementation circular economy. The outcomes of this study help them to firstly make and publish required standards and then define the obligatory period of times for gaining compliance targets. Next, they should provide guidelines about how to incorporate standards. For the transition towards a circular economy, producers and economic activists might be encouraged with tax discounts, simplification of waste management, and awareness campaigns which would be established by policymakers.

There is also an important implication for theory in this paper. The number of research papers that used three aspects of sustainable development as well as technical and risk consideration in the decision-making process in logistics and supply chain area, focusing circular economy. Taking all these dimensions is the reason for the growth in the number of decision criteria that engaged in the selection of alternatives. It leads to difficulty in the decision process for both experts and managers in terms of the computational complexity, regardless of the considered MADM technique(s). Moreover, the more decision criteria we consider for a selection problem, the more data are needed to collect. It usually seems that many of the criteria are ineffective in the final decisions due to overlapping with other criteria. This study contributes to deal this problem without damage to decisions and goal of the problem, which is achieving sustainable development in this research. The expert judgment method is applied in this work can help to sort this type of trouble out in various selection problems, while still supporting the goal of the moot point. We believe this to be the most substantial theoretical implication of the current research.

7 | CONCLUSION

Because of growing the expenditures in all of the industries for production as well as the price of raw materials, today's, the majority of companies are looking for ways which are been neither costly, nor detrimental for nature and the environment. For this porpuse, sustainable dvelopment is considered as goal of goods producers. The circular economy is a valuable strategy that can make all the sustainable development achieveable by using tools like recycling, disposal, reduce, reuse, and so on. In this strategy, logistics is one of the most significant parts. Logistics is the flow of products in a supply chain network include reverse and forward flow among different zones. Indeed, logistics is a key sector of an organization that should be studied accurately. For that reason, the majority of the producers prefer to outsource the logistics activities to 3PLSPs which is not only reduced the costs but also specialized its activities. However, the important point is to select the best and suitable 3PLSP.

This work develops a novel analytical multi-step fuzzy decision-making approach to evaluate all the considered criteria for outsourcing both reverse and forward logistics operations to a 3PLSP in a sustainable circular economy. Fuzzy DEMATEL-ANP is used for evaluating the interrelation among the main criteria and weighting subcriteria. This hybrid technique is improved by using the expert judgment method to decrease the number of criteria due to the overlapping of many criteria regarding their content and context in practice and operation. This development leads to reduce the complexity and difficulty of calculations. The next step is applying the fuzzy COPRAS method to rank alternatives and select the best 3PLSP.

The suggested model is applied in a household appliance manufacturing case study to validate the practicality of the approach. Eighteen experts participated in this research for filling out the questionnaires. Finally, a sensitivity analysis for double checking the sensitivity or robustness of the suggested analytical decision-making model is carried out with changing in criteria weights. Suggested scenarios for sensitivity analysis validate the developed decision-making approach, collected data, and the achieved results by altering the weights of criteria in different situations. The main criteria which are the cause of influence are economic, technical, and environmental, while the social and risk are effect main criteria regarding the results of fuzzy DEMATEL. Economic (cost), quality, and services are the noticeable criteria in this study based on the results of weighting method by fuzzy ANP. The obtained results also indicate that 3PLSP 1 as the first rank and the best one among five alternatives. The economic and social criteria have the most impact in this rank. The 3PLSP 5 is selected as the last (worst) alternative by influencing of economic and technical criteria. This ranking is carried out by fuzzy COPRAS.

There are some directions for future research which are recommended in light of study's limitations. First, the future researcher can use the suggested decision-making model with calculating all the subcriteria instead of main criteria. It may be lead to different or more accurate results that should be tested prior to claiming. Second, scholars can use other feature reduction procedures such as statistical methods. Third, the proposed decision-making model uses for other case studies in different areas in which reverse logistics have been adopted to collecte more reliable data with bigger sample size. Also, other industries can be used such as car parts, glasses, paper, etc. Since the decision model is multi-criteria and flexible other selection problems like supplier, market, source of energy selection can be solved by that.

ACKNOWLEDGEMENTS

Open access funding enabled and organized by Projekt DEAL.

CONFLICT OF INTEREST

Authors have no conflict of interest to declare.

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How to cite this article: Zarbakhshnia, N., Govindan, K., Kannan, D., & Goh, M. (2023). Outsourcing logistics operations in circular economy towards to sustainable development goals. *Business Strategy and the Environment*, *32*(1), 134–162. https://doi.org/10.1002/bse.3122