Science, Engineering and Technology Vol. 6, No. S1, pp. 105-118
www.setjournal.com https://doi.org/10.54327/set2026/v6.is1.387

Performance Evaluation of Municipal Waste Collection Crews Using an Integrated FUCOM–MARCOS Model

Jovo Ateljević[1], Željko Stević[2,3], Boris Novarlić[1], Boris Gitolendia[4], Ilija Tanackov[5]

[1]*Faculty of Economics, University of Banja Luka, Majke Jugovića 4, Banja Luka 78000, Bosnia and Herzegovina.*

[2]*Graduate School of Energy & Environment (KU-KIST GREEN SCHOOL), Korea University, Seoul 02841, Republic of Korea.*

[3]*Department of Mobile Machinery and Railway Transport, Faculty of Transport Engineering, Vilnius Gediminas Technical University, Vilnius 10223, Lithuania.*

[4]*Faculty of Transport Systems and Mechanical Engineering, Georgian Technical University, 77 Kostava Street, Tbilisi 0160, Georgia.*

[5]*Faculty of Technical Sciences, University of Novi Sad, Trg Dositeja Obradovića 6, 21000 Novi Sad, Serbia.*

Abstract

Human resource management today, in an era of rapid technological achievements and a changing work environment, represents a great challenge. Particular attention is being directed toward the digitalization of business operations and technically modern management, while human resources still remain in the background. Teamwork, adaptability to new circumstances and quick response to problem-solving are the central part of this paper. The aim of the paper is to conduct an integrated performance evaluation of utility vehicle crews that collect and transport waste in the city of Doboj (Bosnia and Herzegovina) on a daily basis, using multi-criteria decision-making (MCDM) methods. Five crews (each crew consists of a driver and two support workers) work daily to keep the city clean while properly disposing of municipal waste. The selection of the best-ranked utility vehicle crew for the month of March 2026 was carried out using the FUCOM (Full Consistency Method) and MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) methods. The FUCOM method was used to determine the weights of nine influential criteria, while the MARCOS method was applied to rank five alternatives of utility vehicle crews. The research results showed that alternative A3 was ranked as the best-rated crew in the observed period, achieving the highest value of the utility function f(K3) = 0.878. The value f(K4) = 0.433 belongs to the worst alternative (A4) and represents the lower reference value within the MARCOS model.

Keywords: Human resources, employee performance evaluation, Multi-Criteria Decision Making (MCDM), waste collection and transport vehicles, FUCOM, MARCOS.

1. Introduction

Accelerated global changes are also leading to a transformation in the way everyday business tasks are performed. Comprehensive business decisions go beyond purely linear or purely vertical models of task execution, moving toward a circular model. The combination of automated and human resources improves business efficiency and contributes to the development of a new model of team decision-making. The evaluation of human resources contributes to organizational efficiency and supports the achievement of strategic objectives and long-term organizational sustainability [1]. The quality of managerial decisions improves the organizational climate by which the company should be guided. In low-accumulative branches of the economy, such as municipal services, this approach is even more important. The

Corresponding author: Željko Stević (zeljko.stevic@vilniustech.lt, 172317@korea.ac.kr)
Received: 10 June 2026; Revised: 10 August 2026; Accepted: 28 August 2026; Published: 2 September 2026

collection and transport of non-hazardous municipal waste directly affect the quality of service and human resource management. Utility vehicle crews that provide waste collection and transport services are of particular importance for the entire local community. A clean environment and timely waste disposal contribute to the satisfaction of both citizens and the entire local community.

Although numerous mechanisms for rewarding employees exist in practice, most of them are based on the supervisor' subjective assessment, which may not yield positive results in the long term. On the other hand, studies have shown that there is a remarkable gap between strategic intent and practice [2]. An insufficiently developed system of timely and proper employee rewarding becomes an opportunity but also a challenge, particularly for developing countries [3]. Likewise, employee performance evaluation often does not have a direct impact on managerial decisions, which further reduces its value in practice.

The model of human resource evaluation through periodic employee rewards is directly related to the managerial processes within the organization. It follows from the above that the reward mechanism is not only an operational function but also an integral part of the corporate decision-making system [4]. In order to bridge the gap in the traditional reward system multi-criteria decision-making (MCDM) methods are being increasingly applied, providing a unified evaluation model as a combination of qualitative and quantitative criteria. These methods are particularly applied in the evaluation of human resources, through objective decision-making. Although MCDM methods have numerous advantages, most studies are focused on strategic decision-making and the selection of employees, while their evaluation is still limited [5]. The research for the purposes of this paper is not focused on the development of a new integrated FUCOM (Full Consistency Method) and MARCOS (Measurement Alternatives and Ranking according to COmpromise Solution) model, but on the application of a multi-criteria framework for the evaluation of human resources in the utility sector. Specifically, the human resources who work daily on the collection and transport of waste, using mostly outdated machinery, were evaluated. The performance of crews is observed based on precisely defined criteria that include optimization of transport routes, fuel and lubricant savings, vehicle preservation and operational efficiency. Therefore, it is necessary to develop models that enable a high level of reliability in decision-making. For the purposes of this paper, the FUCOM was used to determine the weights of criteria with a small number of comparisons and the MARCOS method to rank alternatives based on their distance from the ideal and anti-ideal solutions with the aim of ensuring stability of the obtained results [6].

The subject of this research is the evaluation of human resources, specifically the crews of utility vehicles (a driver and two support workers per truck) for the collection and transport of waste in the city of Doboj (Bosnia and Herzegovina, BiH). The aim of the research is to create a model that relates to the objective ranking of alternatives based on multiple criteria, enabling efficient decision-making in the observed company. Therefore, the research question is: Whether the MARCOS and FUCOM method provides a structured and transparent basis for crew evaluation? The aim is to motivate the crews of utility vehicles and encourage a competitive spirit among them, ensuring that the best crew, at the end of each month, receives a particular financial incentive that will contribute to improving the company's operational system in the future. In addition to performing daily work tasks, the motivation for this research is to determine the interrelationship between crews, teamwork and assistance provided to other crews that are unable to perform their regular tasks for certain reasons. The theoretical contribution of the paper is reflected in the extension of existing research in the field of human resource rewarding. In an innovative and systematic way, this creates the potential for long-term job stability of employees. The problem includes unpleasant odors that are an integral part of mixed municipal waste and the migration of employees in these jobs. Only an adequate employee reward system and personal job satisfaction should contribute to the long-term sustainability of the observed company as well as the continuity of its operations. The specific contribution of this research is reflected in the application of the integrated FUCOM-MARCOS model in the process of multi-criteria evaluation of human resources in the waste collection and transport sector. The crews were evaluated using expert assessments. Five experts participated in this research, and their results will be analyzed later in the paper.

2. Literature Review

Contemporary business operations are characterized by continuous adaptation to the high demands of the market, which is constantly changing and transforming. Intellectual capital enters a phase of intense "struggle" with machine learning and gradual market transformation. Artificial intelligence is significantly changing the modern business environment. The shift toward technologically demanding processes reduces the importance of human resources for operational and routine tasks [7]. Research by Wilts et al. [8] showed that AI is particularly transforming the traditional system of non-hazardous municipal waste management into an automated system. Digitalization of business processes is changing traditional models of waste collection and transportation by introducing smart technologies. This particularly applies to the introduction of sensor systems, data processing and optimization of transport routes, which enables the transformation of traditional operational activities and their connection with digital decision-making processes [9]. This reorganization creates a potential opportunity for a transition from a simple linear to an advanced circular waste management model [10]. In this way, human resources and technology are viewed as interconnected with the ultimate goal of a successful model of comprehensive waste management. Therefore, long-term success is only possible if employees adequately apply these technologies in practice. Technological transformation in itself is not sufficient for the projection of a sustainable system of comprehensive waste management. Employee competencies and dedication should contribute to the efficient implementation of advanced technological solutions [10]. Consequently, an extremely small number of studies address human resource valuation at the level of municipal utility vehicle operational crews. Increasing attention is being paid to digitalization, route optimization, and the selection of modern efficiency-tracking systems in waste management.

Studies have shown that with the growth of municipal waste volumes and increasingly complex operational processes, well-trained crews of utility vehicles contribute to its timely disposal [11]. However, the traditional models of waste collection and transportation based on the "door-to-door" principle are considered good practice, but insufficient due to population growth and increasing waste generation from year to year [12]. Modern technologies and well-trained workers [13] contribute to solving the issues of municipal waste disposal in real time.

Research has confirmed that employee performance evaluation contributes to the overall success of an organization [6]. The models of human resource performance measurement play a key role in employee motivation and productivity [14], [15]. Teamwork, transport route optimization and operating cost reduction are only some of the elements that contribute to organizational success. Unlike the manufacturing sector where business processes are technologically standardized, the service sector depends on the behavior of employees in solving specific and extraordinary problems [16]. According to Meyers et al. [17], it has been proven that employee performance is not only the result of their individual but also organizational efforts, which actually encourage motivation and direct their daily behavior. Studies have confirmed that continuous employee training and a developed reward system contribute to the accurate performance of regular work tasks and greater employee engagement [18], [19]. Continuous communication between public utility service providers and the interested public contributes to increasing the value of the services, as well as to general satisfaction in the observed local community. Although these tasks performed by service providers are routine, a high level of precision and a reduction in operational errors are required to ensure maximum efficiency [20]. A single moment of driver inattention while operating a utility truck can cause injuries to crew members, which further emphasizes the importance of mutual coordination and teamwork.

According to Taherdoost and Madanchian [21], MCDM methods are highly useful tools for solving complex decision-making problems, which actually include multiple conflicting criteria. This particularly means that operating costs and technology should be integrated since utility crew performance cannot be observed on the basis of a single indicator, but rather through their combination. Recent studies have shown that modern models based on fuzzy MCDM approaches are more focused on the selection of equipment and systems than on human resources [22]. According to Chakraborty et al. [23], most studies have focused on the selection of alternatives related to equipment and technological approach, while human resource management has also been considered [24], but receiving less attention. Consequently, the municipal sector remains under-researched, and the small number of studies conducted have mainly focused on transport and logistics systems [25].

According to Pamučar et al. [26], the combination of FUCOM and MARCOS methods has proven to be effective, particularly in solving complex problems in the field of transport, and thus also in the transport of municipal waste. Therefore, it represents a valuable integration in the case when it is necessary to make a decision with multiple criteria taken into account. In the field of waste management, not only fuel optimization and transportation route optimization are considered as individual criteria, but also numerous other criteria, which can often be in conflict with one another (e.g., the regular execution of work tasks, providing assistance to other crews, causing damage to vehicles, etc.) [27].

On the other hand, research has proven that the MARCOS method in combination with a fuzzy approach contributes to even greater flexibility in more complex situations [28]. In other words, it may happen that when assessing the performance of an organization, it is based on imprecise and often subjective assessments, and thus the assessors' attitudes may also be subjective. Therefore, the identified gap creates a need for the implementation of a model that includes the human factor in performance evaluation [29], [30]. This statement particularly refers to low-accumulative systems such as waste management, where the quality of service directly affects the sustainability of the system. Stronger coordination between support workers and the crew of the utility vehicle (automated system) will contribute to a positive correlation between satisfied workers and a healthy environment [31], [32].

3. Methods

3.1. FUCOM Method

To obtain weight coefficient values, the FUCOM method, developed by Pamučar et al. [33], was used.

Step 1. Ranking of criteria/sub-criteria using expert preferences.

$$C_{j(1)} > C_{j(2)} > \ldots > C_{j(k)} \tag{1}$$

Step 2. Calculation of the vector of the comparative significance of the evaluation criteria.

$$\Phi = \left(\varphi_{1/2}, \varphi_{2/3}, \ldots, \varphi_{k/(k+1)}\right) \tag{2}$$

Step 3. Defining the constraints of a nonlinear optimization model.

Condition 1.

$$\frac{w_k}{w_{k+1}} = \varphi_{k/(k+1)} \tag{3}$$

Condition 2.

$$\frac{w_k}{w_{k+2}} = \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)} \tag{4}$$

Step 4. Defining a model for determining the final values.

$$\begin{aligned}
&\min \chi \\
&s.t. \\
&\left|\frac{w_{j(k)}}{w_{j(k+1)}} - \varphi_{k/(k+1)}\right| \le \chi, \ \forall j \\
&\left|\frac{w_{j(k)}}{w_{j(k+2)}} - \varphi_{k/(k+1)} \otimes \varphi_{(k+1)/(k+2)}\right| \le \chi, \ \forall j \\
&\sum_{j=1}^{n} w_j = 1, \\
&w_j \ge 0, \ \forall j
\end{aligned} \tag{5}$$

Step 5. Solving the model and obtaining the final weight of the criteria $(w_1, w_2, \ldots, w_n)^T$.

3.2. MARCOS Method

The MARCOS method which has been applied in many studies in different forms [34], [35] is implemented through the following steps and calculations [36], as shown as follows.

Step 1: Formation of an initial decision-making matrix.

Step 2: Formation of an extended initial matrix with the ideal (AI) and anti-ideal (AAI) solution.

$$X = \begin{array}{c} \\ AAI \\ A_1 \\ A_2 \\ \dots \\ A_m \\ AI \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ \begin{bmatrix} x_{aa1} & x_{aa2} & \dots & x_{aan} \\ x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ \dots & \dots & \dots & \dots \\ x_{m1} & x_{m2} & \dots & x_{mn} \\ x_{ai1} & x_{ai2} & \dots & x_{ain} \end{bmatrix} \end{array} \quad (6)$$

$$AAI = \min_i x_{ij} \quad if\ j \in B \quad and \quad \max_i x_{ij} \quad if\ j \in C \quad (7)$$

$$AI = \max_i x_{ij} \quad if\ j \in B \quad and \quad \min_i x_{ij} \quad if\ j \in C \quad (8)$$

Step 3: Normalization of the extended initial matrix (X).

$$n_{ij} = \frac{x_{ai}}{x_{ij}} \quad if\ j \in C \quad (9)$$

$$n_{ij} = \frac{x_{ij}}{x_{ai}} \quad if\ j \in B \quad (10)$$

where elements x_{ij} and x_{ai} represent the elements of the matrix *X*.

Step 4: Determination of the weighted matrix.

$$v_{ij} = n_{ij} \times w_j \quad (11)$$

Step 5: Calculation of the utility degree of alternatives *Ki*.

$$K_i^- = \frac{S_i}{S_{aai}} \quad (12)$$

$$K_i^+ = \frac{S_i}{S_{ai}} \quad (13)$$

where $S_i(i=1,2,..,m)$ represents the sum of the elements of the weighted matrix *V*.

$$S_i = \sum_{i=1}^{n} v_{ij} \quad (14)$$

Step 6: Determination of the utility function of alternatives $f(K_i)$.

$$f(K_i) = \frac{K_i^+ + K_i^-}{1 + \frac{1 - f(K_i^+)}{f(K_i^+)} + \frac{1 - f(K_i^-)}{f(K_i^-)}}; \quad (15)$$

where $f(K_i^-)$ represents the utility function in relation to the AAI solution, $f(K_i^+)$ represents the utility function in relation to the AI solution. Utility functions in relation to the AI and AAI solution are determined.

$$f(K_i^-) = \frac{K_i^+}{K_i^+ + K_i^-} \quad (16)$$

$$f(K_i^+) = \frac{K_i^-}{K_i^+ + K_i^-} \quad (17)$$

Step 7: Ranking the alternatives.

4. Case Study

The aim of this study was to examine the role and significance of human resources that constitute the crew of utility vehicles of the utility company Progres Ltd. Doboj (hereinafter referred to as Progres, BiH), in conducting daily work tasks. The primary goal of the crew is the collection and transport of non-hazardous municipal waste in the city of Doboj. The company Progres operates a fleet of 11 specialized utility vehicles for the specified purposes, powered by Euro 3 and Euro 4 diesel engines, which are prone to frequent breakdowns due to their age and technological obsolescence. However, the analysis includes only five vehicles that are operated daily, while the remaining vehicles represent a so-called reserve in emergency cases. A total of five crews are analyzed in this study. Each crew consists of a driver and two support workers who help physically transport waste from 120-liter bins and 1,100-liter containers to the truck and mechanically load it into the vehicle. The transport routes along which the vehicles move on a daily basis are known in advance (on average between 55 and 75 km). Teamwork is the starting point of the research. Waste is collected from 13,650 households and 1,225 business entities, on a daily basis, throughout the year without exception, between 7:00 a.m. and 3:00 p.m. In order to make the method of evaluating human resources and the potential rewarding of utility vehicle crews clearer, the crews are presented in Table 1, respectively.

Table 1. Truck crews and technical characteristics.

Crew name	Truck year of manufacture	Load capacity (*kg*)	Mileage (*km*)
(A1) MAN M34-J-372	2004	10,750	412,710
(A2) MAN E26-A-502	2003	11,450	648,673
(A3) MAN T32-J-339	2003	10,425	267,864
(A4) IVECO K01-A-552	2003	10,750	435,215
(A5) MAN 058-T-914	2009	9,150	544,713

In Table 1, alternatives A1 to A5 represent the crews of utility trucks. Although the fleet is 17 years old or older with significant mileage (vehicle depreciation lifespan), the human factor is still of great importance for the functioning of the entire system of comprehensive waste management in the city of Doboj. As for the crew members, the drivers have decades of experience in operating utility trucks. The years of drivers' service range from 20 to 35 years, while the support crew members are young people, aged 19 to 33. Therefore, it follows that all five crews are, in terms of human resources, mutually competent for the service they provide, as well as in terms of ability and ease in performing it. The driver of each vehicle represents the team leader who guarantees the proper execution of tasks.

The vehicles that collect waste daily are similar in capacity and year of manufacture except for the A5 crew vehicle, while the mileage is partially different (A2 and A3 crew vehicles), as presented in Table 1. All utility truck drivers agree to operate their assigned trucks on a daily basis as explained in the table above. The same mechanics within Progres carry out truck repairs and also agree that all trucks participating in the business of collecting and transporting waste are of similar performance. Transport routes are precisely defined by the Progres expert team and jobs are equally designed for all crews during the regular execution of work tasks. The terrain configuration and arrangement of waste disposal containers are mapped according to the population density of the location where the waste is disposed. The truck driver is responsible for organizing work during the day, but with respect for the rest of the crew of the same vehicle. Success in carrying out work tasks depends not only on the organization of the crew, but also on the characteristics of the vehicle, the assigned route, the daily mileage traveled and the total amount of collected and transported waste. The interaction between crew members and operational conditions contribute to the success of the tasks performed.

Data collection was carried out in the period from March 1 to March 31, 2026, by field monitoring of utility vehicle crews' operations based on pre-determined criteria. The criteria were defined on the basis of a review of literature and previous studies, practical needs of the company and in cooperation with the management of Progres. The questionnaire consisted of nine criteria that are precisely defined in Table 2.

In order for the experts to be able to determine which crew performs its daily work tasks in the best way and which does not, it was necessary to establish a clear analysis plan. Through field and office work, efforts were made to determine an optimal mechanism for the realistic presentation of the obtained results. Table 3 presents the expert team that evaluated the obtained results.

Specifically, the first three experts presented in Table 3 belong to the company's management, while the other two are external experts. The number of experts was not chosen arbitrarily. The criteria for selecting experts depended on their knowledge of the work of municipal crews on waste collection and transport, the working conditions of the crews, and the defined criteria by which they were evaluated. A limitation of the research was recognized that three out of five experts were from the same organization. The defined number of experts does not eliminate subjective influence nor does it represent a representative statistical sample of the observed organization. Expert assessments are defined as professional assumptions that are specific to the organization that is the subject of analysis in this research. Therefore, five experts were sufficient to conduct the research at the local level.

Table 2. Criteria and measurement method.

Criterion	Description	Method of measurement
(C1) Execution of regular tasks	Daily collection and transport of waste on a defined transport route according to the head of the Mechanization Work Unit (Progres)	Waste collection from all waste disposal containers on the transportation route during the shift. The hygiene around the containers is analyzed - has all the waste been collected?
(C2) Assistance to other crews	It is analyzed whether the crews that finish the shift before the deadline, report to help the crews that are not so efficient. This means helping colleagues to finish their shift on time and to keep the city clean (garbage taken away, containers are disinfected - especially in the summer)	Frequency of assisting other crews who fail to complete a work task (eg how often a crew comes to help other crews if they do not complete their work tasks)
(C3) Timely reporting of technical vehicle issues	The driver and crew members should monitor the condition of the vehicle on a daily basis. The vehicles are old and depreciated, and breakdowns are frequent	Suggesting problems to superiors during the daily collection and transportation of waste (persons to be informed are the general director and head of the Mechanization Work Unit (Progres))
(C4) Reporting field issues to the supervisor	All observations that can affect the efficiency of the crew's work in the execution of regular and extraordinary tasks	Indication of inadequate disposal of waste (wild landfills) and special illegal types of waste that are disposed of outside the law (solid and bulky waste, animal waste, electronic waste and similar). Attention is also drawn to all other deviations that are not in accordance with the local law on waste management and the municipal order of the city of Doboj. Illegal landfills increase Progres' operating costs.
(C5) Recording of new users not registered in the business database	Notes on new service users who are not registered in the Progres database	Notes from the field are submitted to the Progres Administration. The invoicing service registers new users. Each registered user affects the increase in the revenue of the utility company Progres. In this way, the potential salaries of employees also grow.
(C6) Transport route optimization	Collection and transport of waste according to the "door-to-door" principle without idling and multiplying the transport route	The time necessary for collecting, transporting and depositing waste. Breakfast break is included as well as unforeseen circumstances or truck breakdowns
(C7) Damage to the vehicle	Has the vehicle been damaged (traffic accidents, physical damage, etc.)	Reporting of damage during an actual event on the field (the resulting damage must not be hidden or kept secret from the superior)
(C8) Fuel optimization	Total daily fuel consumption	Multiplication of the transport route, idling, unforeseen circumstances that affect fuel consumption (additional collection of waste on the same transport route - for example, an increase in the daily amount of waste deposited in certain containers)
(C9) Post-shift vehicle maintenance (washing)	Maintenance of vehicle hygiene - washing after the end of the shift and disinfection. It is important that there is no corrosion and deterioration of the loading space on the truck	Those in charge of monitoring the arrival of trucks in the company's business circle monitor whether the crews wash the trucks daily and the like. The trucks are located at Poljice bb, Doboj and remain in garages during the rest of the day and during the night when they are not used for work.

Table 3. Expert team.

Expert	Managerial Competencies	Years of Experience
General Director of Progres	Decades of experience in human resource management in the company	32
Head of the Mechanization Work Unit (Progres)	Most competent person for organizing utility truck crews and transport routes	30
Assistant Head of the Mechanization Work Unit (Progres)	Monitors fuel and lubricant consumption in the company and proposes measures for inefficient trucks	10
Independent Expert for Comprehensive Waste Management	Planning and organization of the overall waste and human resource management system	31
Expert for Utility Trucks	One of the few experts for old utility trucks in BiH	35

In order to reduce the subjective perception when evaluating human resources, the management was purposefully included in the analysis to obtain an objective assessment. Previous "informal" experience in knowing colleagues who are members of utility truck teams will contribute to a clear and reliable picture, which will be of particular benefit to Progres in the coming period. This actually means that, based on the defined criteria used for evaluating human resources, as well as the expertise and long-term experience of the experts, a clear and precise picture will be formed regarding the crews that keep the city clean and healthy for its citizens on a daily basis.

Semi-structured interviews with the Progres expert team were conducted on March 11, 2026 between 8:00 a.m. and 11:00 a.m. The goal was to determine the company's vision regarding the renewal of the fleet, as well as potential (partial) electrification and training of human resources for new technologies. The interview results unanimously confirmed the thesis that the company aims for a better positioning on the regional market by modernizing its vehicle fleet and gradually moving toward an eco-friendly vehicle fleet with zero Carbon dioxide (CO_2) emissions, i.e., toward carbon-neutral transport. The continuous increase in vehicle repair costs, the lack of spare parts and constant breakdowns influenced the management's decision, which represents the long-term vision of Progres. In addition, it was concluded that human resources continue to be an indispensable element in developing a successful organization in the long term. Education and professional training for future advanced technologies and an electric fleet or the renewal of the existing fleet of vehicles with internal combustion engines were proposed.

Crews were evaluated by five experts. Each expert independently evaluated all five crews according to nine defined criteria. A numerical scale from 1 to 9 was used to evaluate the criteria. The experts assigned their ratings based on the defined characteristics and performance of the crews that were observed in the specified period. The evaluations of all five experts were taken into account to obtain the final value of each criterion for each crew. All five experts from Monday to Friday participated in the successive observation of crews. Although they could not physically accompany all five crews at the same time, they recorded observations that were of particular importance to them in order to make a final conclusion about the best crew for the observed period. They arranged the data in the office, separately for the sake of transparency. The experts consulted each other for details, but only for the purpose of giving a final opinion if necessary. Each expert conducted the evaluation according to the specified template. Quantitative indicators were taken from the assistant head of the Mechanization Work Unit (tachograph tape reading, fuel consumption, mileage, vehicle breakdowns, etc.). Also, the assistant had all the data during the observed month, which refer to the end of the shift for each vehicle, maintenance of vehicle hygiene, overtime hours and completed tasks. If it happened that vehicles came to the garage after working hours, the security officer at Mechanization (the location where all the trucks are located) recorded all additional observations. From the semi-structured interview with the general manager, it was concluded that the quantitative data obtained during the research (fuel consumption, mileage, breakdowns and damage to vehicles, etc.) should not be published in the research of this paper. The general director approved the publication of the license plates of the trucks that participated in the survey. The identity of the crew members of all five trucks was not known to outside experts. The only information was that they belong to the team according to the designations from A1 to A5. All crews agreed to participate in the research in the manner previously described. Management (three experts who participated in the research) was introduced in order to really have an insight into the real working conditions and the behavior of the crews during the collection and transportation of waste. Management has estimated that daily interaction with employees creates a realistic picture from which their work performance can be seen. For this reason, in addition to the experts from the company, two external experts with decades of experience in these jobs were also included in the research.

Therefore, three members of management were targeted in the research to see the contribution made by each crew. Two external experts are among the most competent people in BiH for improving human resources and increasing employee motivation. All experts were given identical tasks for assessing employee competencies.

Regarding the MCDM model, the results obtained are presented below. First, the weights of the criteria were calculated based on expert’s inputs (Table 4) and used to evaluate human resources.

Table 4. Comparative priorities of criteria for all experts.

E1	C8	C6	C4	C1	C2	C7	C3	C5	C9
	1	1.5	1.6	1.9	2.2	2.3	2.7	3.1	3.8
E2	C8	C6	C4	C1	C2	C7	C3	C5	C9
	1	1.8	1.9	2	2.1	2.6	3.1	3.3	4.5
E3	C8	C6	C4	C1	C2	C7	C3	C5	C9
	1	1.3	1.5	1.7	1.8	1.9	2.2	2.3	3.1
E4	C8	C6	C4	C1	C2	C7	C3	C5	C9
	1	1.5	1.9	2.2	2.9	3.5	3.6	3.7	4.9
E5	C8	C6	C4	C1	C2	C7	C3	C5	C9
	1	1.5	1.6	1.7	1.8	1.9	2.2	3.8	4.5

The results of applying the FUCOM method are shown in Figure 1. For each expert, deviation from full consistency is equal to zero, while final weights have been obtained using average mean.

	E1	E2	E3	E4	E5	Final
C1	0.113	0.111	0.145	0.113	0.113	**0.119**
C2	0.097	0.090	0.125	0.086	0.107	**0.101**
C3	0.079	0.117	0.099	0.069	0.136	**0.100**
C4	0.134	0.071	0.085	0.071	0.093	**0.091**
C5	0.069	0.075	0.082	0.067	0.054	**0.069**
C6	0.143	0.123	0.111	0.248	0.120	**0.149**
C7	0.093	0.129	0.104	0.131	0.204	**0.132**
C8	0.214	0.233	0.188	0.165	0.128	**0.186**
C9	0.056	0.052	0.061	0.051	0.045	**0.053**

Figure 1. Criterion weights after applying the FUCOM method.

The analysis conducted using the FUCOM method leads to the conclusion that, when comparing nine criteria, the fuel optimization criterion (C8) carries the highest weight for decision-makers, with a weight of 0.186. This is followed by the criterion related to transport route optimization (C6) with a weight of 0.149. Next, the third most important criterion is C7 – damage to the vehicle, with a weight of 0.132, while the next in terms of importance is criterion C1 – execution of regular tasks, with a weight of 0.119. It is important to emphasize that there was collegiality in assisting utility vehicle crews that were unable to complete their regular tasks on time. Accordingly, the high fifth place is taken by criterion C2 with a weight of 0.10.

Based on the results obtained in this research, the criteria related to reporting technical vehicle issues (C3) and field issues to the supervisor (C4) are at the very bottom of priorities. The least significant criteria according to the experts' assessments relate to the low level of responsibility of the crews, which affects the recording of unregistered users of utility services (C5), while the last in terms of significance with a weight of 0.053 is C9 – post-shift vehicle hygiene maintenance.

After calculating the weights, the evaluation of human resources was carried out using the MARCOS method. The initial matrix (Table 5) has been obtained using geometric mean to average separate matrices for five experts. For assessing human resources, decision makers have used a scale from extremely poor (1) to extremely good (9). It is important to note that all criteria in the model are beneficial because experts take into account the nature of the criteria at the beginning, and if a criterion is cost-type, experts give the highest values in the initial matrix for the minimum quantitative value. In that way criteria C7 and C8 that are cost type have transformed into benefit type.

Table 5. Initial matrix for MARCOS method.

	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	8.360	4.282	4.573	3.758	1.149	6.325	7.017	7.950	8.002
A2	6.284	2.512	2.512	3.170	1.149	4.478	5.800	6.645	7.277
A3	8.790	8.002	8.790	8.790	3.845	8.790	8.106	8.790	8.139
A4	5.502	1.644	4.959	3.366	1.149	3.898	5.633	4.076	6.355
A5	8.165	1.974	3.438	1.783	1.149	6.892	6.000	6.274	6.871

After applying MARCOS procedure results are shown in Table 6.

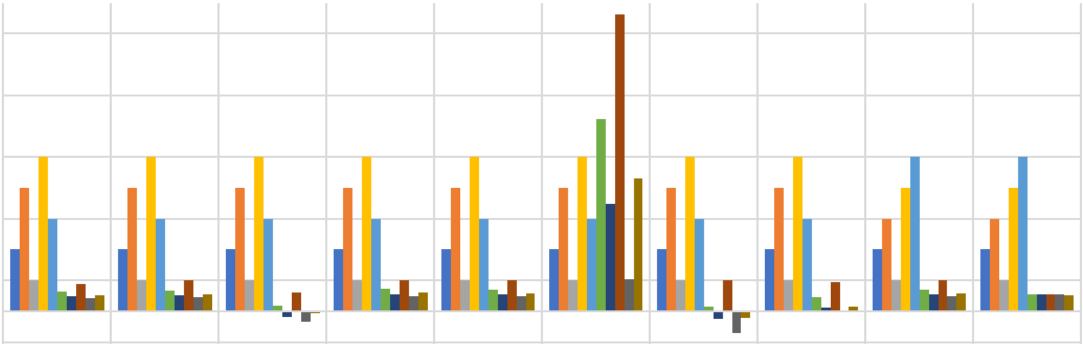
Table 6. Final results obtained by the MARCOS method.

	Si	Ki-	Ki+	fK-	fK+	fKi	**Rank**
AAI	0.448	1.000					
A1	0.720	1.607	0.720	0.310	0.690	0.633	2
A2	0.557	1.242	0.557	0.310	0.690	0.489	4
A3	1.000	2.230	1.000	0.310	0.690	0.878	**1**
A4	0.493	1.099	0.493	0.310	0.690	0.433	5
A5	0.606	1.351	0.606	0.310	0.690	0.532	3
AI	1.000		1.000				

Based on the results shown in Table 6, alternative A3 achieves the highest final MARCOS value f(Ki)=0.878, taking first place in the ranking. It is followed by A1 with f(Ki)=0.633, A5 with f(Ki)=0.532, A2 with f(Ki)=0.489 and A4 with f(Ki)=0.433. The differences between the utility function values for crews ranked from second to fifth place are not large, which indicates a relatively uniform level of their performance. Alternative A3 for the observed period also achieves the highest value of Si=1.000, while the value of the anti-ideal alternative is Si=0.448. Therefore, this crew can be assessed as the most efficient crew for the month of March, 2026, according to all observed parameters that were subject to evaluation. The results obtained in this research provide company management with an objective picture when making decisions on rewarding employees.

Based on the defined criteria and continuous improvements in business processes, monetary compensation may be introduced in the future as a reward for the crew of the month. Only five operational crews engaged in waste collection and transport on a monthly basis provide even a more realistic picture for selecting the best crew for the observed period.

The obtained results were verified through a comparative analysis with nine other MCDM methods, as shown in Figure 2, and sensitivity analysis through 54 simulated scenarios (Figure 3).



	MARCOS	ARAS	MABAC	SAW	WASPAS	CoCoSo	RAWEC	EDAS	CRADIS	AROMAN-M
A1	2	2	2	2	2	2	2	2	2	2
A2	4	4	4	4	4	4	4	4	3	3
A3	1	1	1	1	1	1	1	1	1	1
A4	5	5	5	5	5	5	5	5	4	4
A5	3	3	3	3	3	3	3	3	5	5
A1	0.633	0.681	0.167	0.720	0.701	6.237	0.156419918	0.470	0.685	0.557
A2	0.489	0.521	-0.171	0.557	0.537	3.473	-0.25588288	0.134	0.536	0.546
A3	0.878	1.000	0.614	1.000	1.000	9.615	1	0.956	1.000	0.560
A4	0.433	0.469	-0.327	0.493	0.478	1.023	-0.70943678	0.002	0.481	0.539
A5	0.532	0.560	-0.058	0.606	0.572	4.294	-0.20837009	0.146	0.579	0.531

Figure 2. Results of comparative analysis.

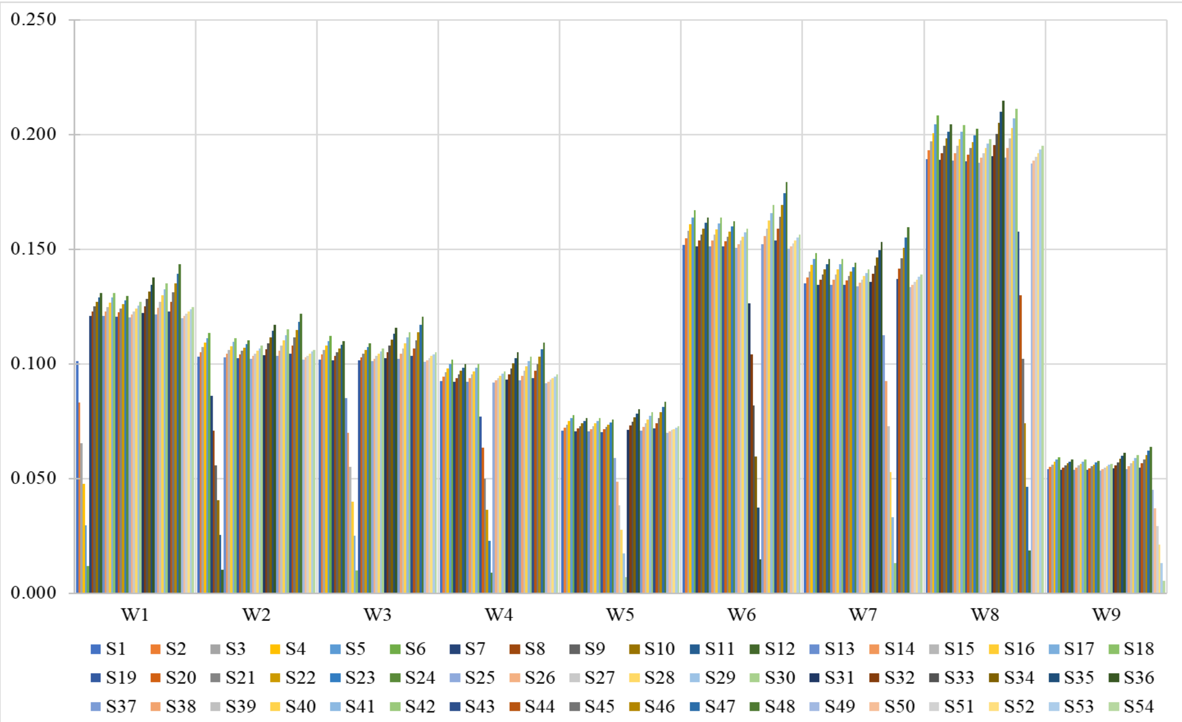


Figure 3. Simulated criteria weights in sensitivity analysis.

The previously obtained results were confirmed through overall comparative analysis, and sensitivity analysis, as no changes occurred in the ranking positions of human resources in transport within the observed research.

5. Managerial implications

Although the topic of this paper is highly contemporary, it is necessary to emphasize certain methodological limitations. The results obtained in this research are relevant and applicable to human resource management for the local company Progres using the MARCOS method. Although the integrated FUCOM-MARCOS approach was applied for the systematic evaluation of human resource competencies, certain limitations of the research are still evident. There is a concern about subjective influence when defining the criteria and determining their relative importance. On the other hand, the potential subjectivity of expert evaluations within the FUCOM method can be particularly questioned. Therefore, special limitations in this paper are one company that is the subject of analysis, five utility crews and the validation of their work over the observed period of one month. In addition, it is important to note the non-standardized transport routes, the absence of time validation and the potential bias of the evaluators. Future research should include data related to the mileage traveled during the shift, the total amount of waste collected during the day, the operational life of the vehicle and the permissible load capacity as well as the geographical characteristics of the transport route.

After a detailed analysis of the research results, it is concluded that Progres does not meet the technical requirements for advanced waste management with its existing vehicles. The age of the vehicle fleet and the entire fleet, with internal combustion engines, potentially represent an even greater issue in the near future. The trucks are not equipped with a mechanism for the technological installation of devices for electronic tracking of the amount of waste collected at any time. In this way, there is no digital communication between the crew of utility vehicles and the information collection and processing center. Communication is carried out via telephone and email, but only during the period when Progres provides the service (from 7:00 a.m. to 3:00 p.m., daily). The amount of collected and transported waste is known only after it is deposited at the regional landfill of the city of Doboj, which is located three kilometers from the city. The proximity of the landfill represents a positive factor from the perspective of optimizing the operating costs of Progres.

On the other hand, after a semi-structured interview with three experts, who are the members of the management of Progres, it was concluded that the company should gradually move from the so-called partial to a predominantly integrated evaluation model, with particular emphasis on human resources. This actually means that human resource performance is no longer viewed only through the amount of waste collected on a daily/weekly or monthly basis, but through the synergy of all interconnected factors. Teamwork, regular work task execution, fuel or lubricant cost optimization, etc., represent a set of activities, i.e., a new viewpoint. The combined FUCOM-MARCOS method reduces subjectivity in assessing the performance of utility vehicle crews and increases transparency in decision-making and human resource evaluation.

The approach has positive effects on the development of a new mechanism for objective and transparent employee rewarding. The defined criteria and their weights contribute to a better understanding of crew members and their goals, while after ranking the crews, clear decisions are made regarding the same goals. In this way, the possibility of conflict situations within the organization is eliminated.

The company Progres should focus on the simpler evaluation of human resources, given that monthly results are a direct consequence of better organization within the crew, as well as teamwork – providing assistance to other crews that are unable to complete their regular tasks within the required period.

The research was conducted in BiH, so its applicability is limited to the observed geographical area. The obtained research results can serve as a basis for comparative analysis in both developing and developed countries, with the aim of comparing similar systems and practices. Therefore, the proposed model has positive implications for strategic management in the organization, as it links operational requirements with the quality of the utility service, and thus the sustainability of the system. Using this model, it is possible to evaluate all Progres crews in real time, through a stable and practical tool for decision-making based on real field data. Future research should test the stability of rankings over several months and among comparable companies.

6. Conclusion

The limited level of communication between the crews of municipal vehicles and the logistical support that monitors the waste flow on a daily basis represents one of the starting points of this work. The utility vehicles that are the subject of analysis are two or more decades old. The only evident investment in machinery refers to the improved equipment of trucks. The human factor, i.e., human resources, which should be the link between the machinery and the success in performing work tasks, once again does not take a central position.

However, an integrated FUCOM-MARCOS model was developed to overcome the aforementioned limitations. The aim was to perform a realistic evaluation of human resources that constitute the crew of utility vehicles. Based on the analysis of the obtained research results, it is evident that for the month of March 2026, the A3 crew achieved the best result according to all observed parameters. During the research period, the A3 crew achieved the highest rank according to the FUCOM-MARCOS model, which shows the best result according to the observed crews and the defined criteria. The analysis shows that this crew should be recommended for a financial bonus for the period under review, relative to the remaining four crews. The findings also provide objective insight into the situation in the field. This actually means that the developed model showed a more objective but also more reliable evaluation of human resources in the utility sector in practice. At the same time, this model helps the management of Progres in adopting a fair reward system within the company. It is important to point out that the obtained result is related only to the period from March 1 to March 31, 2026, which in the long run does not necessarily mean that the A3 crew will achieve the best result again.

The scientific contribution of the paper is reflected in the introduction of the MCDM method in the waste management sector through employee performance evaluation. The defined model provides a transparent framework for evaluating employee performance based on defined criteria and expert assessments. The integrated FUCOM-MARCOS model contributes to a more uniform evaluation of utility vehicle crews. Future research should be focused on the application of the model in all utility companies in BiH as well as in the Western Balkans region. The research should be expanded by including a larger number of both alternatives and criteria, which will be applied to all other utility companies in the evaluation of employee performance.

This research represents one of the rare studies that considers the measurement of human resource performance in a municipal waste transport company in transition countries. The results obtained confirm that the integrated MCDM model may represent a sustainable and long-term solution for improving the process of fair employee rewarding while reducing the subjective factor that influences this decision.

Competing Interest Statement

Željko Stević serves as a Guest Editor of the Special Issue. He had no involvement in the peer-review process, editorial evaluation, or final decision regarding this manuscript. The other authors declare no competing interests.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author, upon reasonable request.

References

[1] A. Albloush, M. A. Jarrah, M. Alghizzawi, P. Bianchi, A. Alkhatib, and S. A. Lehyeh, "Exploring the moderating role of green human resources and green climate: The impact of corporate social responsibility on environmental performance," *Uncertain Supply Chain Management*, vol. 12, no. 2, pp. 771–778, 2024, doi: 10.5267/j.uscm.2024.1.009.

[2] A. Tarigan, A. Gustomo, and Y. R. Bangun, "Are performance appraisals in the public sector fair? Exploring bias and best practices," *Cogent Business & Management*, vol. 12, no. 1, Art. no. 2458760, Feb. 2025, doi: 10.1080/23311975.2025.2458760.

[3] G. Emejulu, "Employee Rewards and Its Performance Implication: A South Eastern Nigeria Experience," *Asian Journal of Economics, Business and Accounting*, vol. 15, no. 2, pp. 8–15, May 2020, doi: 10.9734/ajeba/2020/v15i230209.

[4] M. C. Tavares and M. Vaz, "Rethinking Performance Evaluation: Strategic Alignment in the Service Sector Through a Case-Based Framework," *Administrative*

Sciences, vol. 15, no. 10, Art. no. 390, Oct. 2025, doi: 10.3390/admsci15100390.

[5] Ž. Stević and N. Brković, “A Novel Integrated FUCOM-MARCOS Model for Evaluation of Human Resources in a Transport Company,” *Logistics*, vol. 4, no. 1, Art. no. 4, Feb. 2020, doi: 10.3390/logistics4010004.

[6] Ž. Stević, B. Novarlić, and M. Kchaou, “Assessment of Human Resources Performance in Urban Maintenance Tasks: An MCDM Approach,” *Journal of Organizations, Technology and Entrepreneurship*, vol. 2, no. 1, pp. 39–51, Mar. 2024, doi: 10.56578/jote020104.

[7] V. Franki, D. Majnarić, and A. Višković, “A Comprehensive Review of Artificial Intelligence (AI) Companies in the Power Sector,” *Energies*, vol. 16, no. 3, Art. no. 1077, Jan. 2023, doi: 10.3390/en16031077.

[8] H. Wilts, B. R. Garcia, R. G. Garlito, L. S. Gómez, and E. G. Prieto, “Artificial Intelligence in the Sorting of Municipal Waste as an Enabler of the Circular Economy,” *Resources*, vol. 10, no. 4, Art. no. 28, Mar. 2021, doi: 10.3390/resources10040028.

[9] A. Lakhouit, “Revolutionizing urban solid waste management with AI and IoT: A review of smart solutions for waste collection, sorting, and recycling,” *Results in Engineering*, vol. 25, Art. no. 104018, Mar. 2025, doi: 10.1016/j.rineng.2025.104018.

[10] M. Graczyk-Kucharska, “Human Resources Responsibilities in Logistic System of Waste Management for Sustainable Growth and Circular Economy,” *European Research Studies Journal*, vol. XXIV, Special Issue 2 - Part 3, pp. 221–233, Dec. 2021, doi: 10.35808/ersj/2714.

[11] A. Salazar-Adams and C. Ramirez-Figueroa, “Organization, capital, and human resource factors influencing waste collection efficiency in Mexico,” *Utilities Policy*, vol. 88, Art. no. 101747, Jun. 2024, doi: 10.1016/j.jup.2024.101747.

[12] D. B. Olawade, O. Fapohunda, O. Z. Wada, S. O. Usman, A. O. Ige, O. Ajisafe, and B. I. Oladapo, “Smart waste management: A paradigm shift enabled by artificial intelligence,” *Waste Management Bulletin*, vol. 2, no. 2, pp. 244–263, Jun. 2024, doi: 10.1016/j.wmb.2024.05.001.

[13] R. Alshaikh and A. Abdelfatah, “Optimization Techniques in Municipal Solid Waste Management: A Systematic Review,” *Sustainability*, vol. 16, no. 15, Art. no. 6585, Aug. 2024, doi: 10.3390/su16156585.

[14] H. Somu, A. M. Nasurdin, and T. C. Ling, “Linking High Performance Human Resource Management Practices (HPHRMPs) And Motivation To Job Performance: A Model Development,” *in Progressing Beyond and Better: Leading Businesses for a Sustainable Future*, vol. 88, pp. 893–902, Oct. 2020, doi: 10.15405/epsbs.2020.10.81.

[15] R. Hanandeh, M. Alharafsheh, A. Albloush, S. M. A. Lehyeh, and Q. Kilani, “The impact of entrepreneurship self-concept, work motivation, and risk taking on human resource department performance and business overall performance at Jordan private universities,” *Uncertain Supply Chain Management*, vol. 12, no. 1, pp. 143–150, 2024, doi: 10.5267/j.uscm.2023.10.010.

[16] Z. Ouabi, K. Douayri, F. Barboucha, and O. Boubker, “Human Resource Practices and Job Performance: Insights from Public Administration,” *Societies*, vol. 14, no. 12, Art. no. 247, Nov. 2024, doi: 10.3390/soc14120247.

[17] M. C. Meyers, M. van Woerkom, and R. Bauwens, “Stronger together: A multilevel study of collective strengths use and team performance,” *Journal of Business Research*, vol. 159, Art. no. 113728, Apr. 2023, doi: 10.1016/j.jbusres.2023.113728.

[18] A. Suhail, K. van de Voorde, T. Steen, and C. Meeusen, “Exploring the links between human resource practices, employee outcomes and performance at the individual and team levels,” *Asia Pacific Management Review*, vol. 30, no. 4, Art. no. 100399, Dec. 2025, doi: 10.1016/j.apmrv.2025.100399.

[19] A. Bos-Nehles, K. Townsend, K. Cafferkey, and J. Trullen, “Examining the Ability, Motivation and Opportunity (AMO) framework in HRM research: Conceptualization, measurement and interactions,” *International Journal of Management Reviews*, vol. 25, no. 4, pp. 725–739, Mar. 2023, doi: 10.1111/ijmr.12332.

[20] B. B. Olwa and D. Mwesigwa, “Stakeholder Participation and Solid Waste Management in Lira City East Division,” *Journal of Environment*, vol. 3, no. 2, pp. 63–88, Sep. 2023, doi: 10.47941/je.1445.

[21] H. Taherdoost and M. Madanchian, “Multi-Criteria Decision Making (MCDM) Methods and Concepts,” *Encyclopedia*, vol. 3, no. 1, pp. 77–87, Jan. 2023, doi: 10.3390/encyclopedia3010006.

[22] Y. Duan, Ž. Stević, B. Novarlić, S. Hashemkhani Zolfani, Ö. F. Görçün, and M. Subotić, “Application of the Fuzzy MCDM Model for the Selection of a Multifunctional Machine for Sustainable Waste Management,” *Sustainability*, vol. 17, no. 6, Art. no. 2723, Mar. 2025, doi: 10.3390/su17062723.

[23] S. Chakraborty, P. Chatterjee, and P. P. Das, “Measurement Alternatives and Ranking according to Compromise Solution (MARCOS) Method,” *in Multi-Criteria Decision-Making Methods in Manufacturing Environments*, Apple Academic Press, pp. 297–307, Aug. 2023, doi: 10.1201/9781003377030-27.

[24] S. Ammirato, A. M. Felicetti, R. Linzalone, V. Corvello, and S. Kumar, “Still our most important asset: A systematic review on human resource management in the midst of the fourth industrial revolution,” *Journal of Innovation & Knowledge*, vol. 8, no. 3, Art. no. 100403, Jul. 2023, doi: 10.1016/j.jik.2023.100403.

[25] A. B. P. S. Neto, C. L. Simões, and R. Simoes, “Optimization of municipal solid waste collection system: systematic review with bibliometric literature analysis,” *Journal of Material Cycles and Waste Management*, vol. 26, no. 4, pp. 1906–1917, May 2024, doi: 10.1007/s10163-024-01966-y.

[26] D. Pamucar, F. Ecer, and M. Deveci, “Assessment of alternative fuel vehicles for sustainable road

transportation of United States using integrated fuzzy FUCOM and neutrosophic fuzzy MARCOS methodology," *Science of The Total Environment*, vol. 788, Art. no. 147763, Sep. 2021, doi: 10.1016/j.scitotenv.2021.147763.

[27] C. X. Ferreira, M. S. Matias, and A. B. de Castilhos Júnior, "Integrated assessment in municipal solid waste management: A discussion from models to indicators," *International Journal of Environment and Waste Management*, vol. 34, no. 2, pp. 209–227, 2024, doi: 10.1504/ijewm.2024.139238.

[28] M. Kovač, S. Tadić, M. Krstić, and M. B. Bouraima, "Novel Spherical Fuzzy MARCOS Method for Assessment of Drone-Based City Logistics Concepts," *Complexity*, vol. 2021, no. 1, Art. no. 2374955, Dec. 2021, doi: 10.1155/2021/2374955.

[29] N. Ferronato and V. Torretta, "Waste Mismanagement in Developing Countries: A Review of Global Issues," *International Journal of Environmental Research and Public Health*, vol. 16, no. 6, Art. no. 1060, Mar. 2019, doi: 10.3390/ijerph16061060.

[30] A. M. Saks, "Antecedents and consequences of employee engagement," *Journal of Managerial Psychology*, vol. 21, no. 7, pp. 600–619, Oct. 2006, doi: 10.1108/02683940610690169.

[31] E. Papadimitriou, C. Schneider, J. Aguinaga Tello, W. Damen, M. Lomba Vrouenraets, and A. ten Broeke, "Transport safety and human factors in the era of automation: What can transport modes learn from each other?" *Accident Analysis & Prevention*, vol. 144, Art. no. 105656, Sep. 2020, doi: 10.1016/j.aap.2020.105656.

[32] G. Gabdullina, M. Gilmanov, A. Akhmetgareeva, S. Khusainova, M. Khamidullin, and G. Gareeva, "Assessment of the resource utilization efficiency of transport companies," *Transportation Research Procedia*, vol. 63, pp. 1055–1060, 2022, doi: 10.1016/j.trpro.2022.06.106.

[33] D. Pamučar, Ž. Stević, and S. Sremac, "A New Model for Determining Weight Coefficients of Criteria in MCDM Models: Full Consistency Method (FUCOM)," *Symmetry*, vol. 10, no. 9, Art. no. 393, Sep. 2018, doi: 10.3390/sym10090393.

[34] X. Peng, H. Garg, and Z. Luo, "When content-centric networking meets multi-criteria group decision-making: Optimal cache placement policy achieved by MARCOS with q-rung orthopair fuzzy set pair analysis," *Engineering Applications of Artificial Intelligence*, vol. 123, Art. no. 106231, Aug. 2023, doi: 10.1016/j.engappai.2023.106231.

[35] M. Blagojević, D. Blagojević, A. Danilevičius, E. Krmac, and S. A. Biancardo, "Application of the FUCOM and MARCOS methods for selecting logistics service providers," *Journal of Intelligent Management Decision*, vol. 4, no. 4, pp. 288–297, 2025, doi: 10.56578/jimd040404.

[36] Ž. Stević, D. Pamučar, A. Puška, and P. Chatterjee, "Sustainable supplier selection in healthcare industries using a new MCDM method: Measurement of alternatives and ranking according to COmpromise solution (MARCOS)," *Computers & Industrial Engineering*, vol. 140, Art. no. 106231, Feb. 2020, doi: 10.1016/j.cie.2019.106231.