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MCDM Methods for Selection of Handling Equipment in Logistics: A Brief Review

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ABSTRACT

This review considers the application of multiple-criteria decision-making (MCDM) methods in the evaluation process of handling equipment in logistics. In order to present a current review of research papers, 21 articles published in the period from 2010 to date were analyzed. All research papers were searched using the Google Scholar web search engine. This paper presents various MCDM methods used to select equipment such as forklifts, cranes, conveyors, automatically guided vehicles, autonomous mobile robots, and reach stackers in warehouses, ports, city logistics, as well as intermodal transport. We analyzed research papers related to the application of MCDM methods including AHP, MABAC, SWARA, ARAS, FUCOM, CRITIC, and MARCOS, as well as various fuzzy methods. As the studies analyzed in the paper have been published from 2010 to the present, this indicates the importance and relevance of this area of research. The purpose of this paper is to encourage additional research in this area and provide a summary of the most recent studies in this field. The results of the paper showed that the most used handling equipment was the conveyor.

1. Introduction

Handling equipment in the logistics sector is a very broad term that includes various types of equipment used for the transportation and handling of goods and materials. Examples of this equipment are forklifts, pallet racks, conveyors, elevators, cranes, loaders, belt conveyors, and other similar equipment. Handling equipment in logistics should be made of high-quality materials and should be resistant to wear and tear. Also, it should be reliable, safe to operate, and easy to maintain. In addition, handling equipment must be adaptable and flexible to adjust to different types of cargo and changing operational conditions. The role of handling equipment in the logistics sector is extremely important. Effective handling of equipment is key to optimizing logistics processes, reducing costs, and increasing productivity. However, selecting the right handling equipment can be

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a challenging task as there are numerous options on the market. It is in these situations that multiple-criteria decision-making (MCDM) methods show their value.

MCDM methods are mathematical techniques used to make decisions when there are different criteria or goals to consider. These methods allow the evaluation and ranking of alternatives, which can be useful in the context of the selection of handling equipment in logistics. Application of MCDM methods may include various criteria used to evaluate handling equipment including cost, reliability, performance, adaptability, safety, etc. These methods enable the analysis of all those criteria as a whole, taking into account their interrelationship and weight. Ultimately, the application of MCDM methods can lead to a better understanding of the advantages and disadvantages of different logistics handling equipment options, which can help in making the right and best decision. This can ensure the optimal handling of equipment, reduction of costs, and increase the efficiency of logistics processes. Therefore, the application of MCDM methods to evaluate handling equipment in logistics represents an important and useful approach that can improve the operations of logistics companies.

Further, the paper presents the methodology describing a short research procedure and the primary results of the review paper with certain features of the literature analyzed. Then, in individual four sections, i.e. intermodal transport, storage systems, logistics centers, and industrial logistics, the subject of each collected article is described in detail.

2. Methodology

Figure 1 depicts the methodology of the study. This review paper consists of the literature collected on the subject of the application of MCDM methods for the evaluation of handling equipment in logistics.

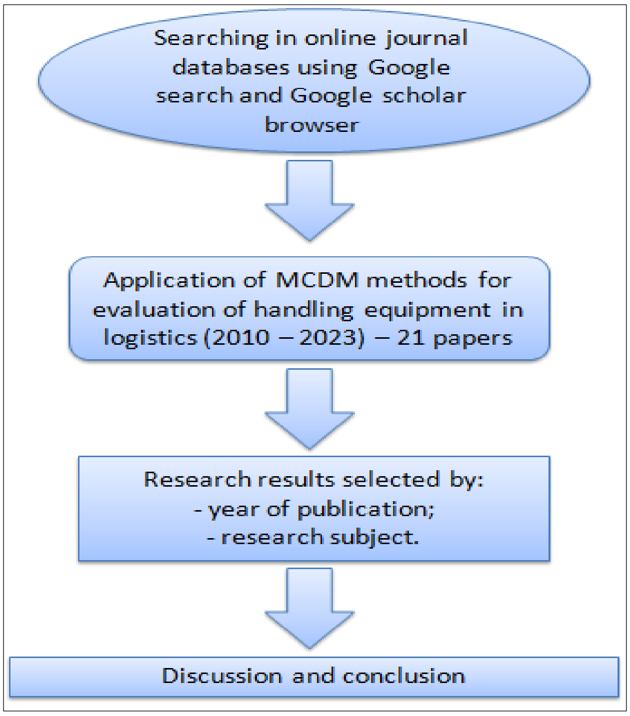

Fig. 1. Research procedure

For the research itself, searches were done in the online databases of various scientific journals, both using the Google search engine and Google Scholar. A large number of articles were found through the search, however, due to the impossibility of full access to particular articles, 21 that completely corresponded to the subject, and which were published in the period 2010-2023, were considered. Some articles focus on a large number of handling equipment and several equipment types are analyzed as part of one article, while some articles focus on only one type of equipment, e.g. as is the case with forklifts.

2.1 Primary Results

Based on Table 1, it can be concluded that the largest number of articles, three out of a total of 21 articles, which is 14.29 %, is from the journal "Expert System with Applications". In the following journal "Decision Making: Applications in Management and Engineering", two articles were published, which is 9.52 %, as well as in "Wireless Networks" and "Sustainability". One article was found in other journals and conferences. It should be emphasized that these journals have significant influence and greatly contribute to science with the articles published in them.

Table 1
Number of articles by journals and conferences

Publication outlet	Numbers	Percentages (%)
Promet -Traffic & Transportation	1	4.76
Wireless networks	2	9.52
Expert System With Applications	3	14.29
Decision Making: Applications in Management and Engineering	2	9.52
Facta Universitatis, Series: Mechanical Engineering	1	4.76
Jordan Journal of Mechanical and Industrial Engineering	1	4.76
Transport Means 2020	1	4.76
International Journal of Computer Integrated Manufacturing	1	4.76
Logistics International Conference, Belgrade	1	4.76
International Journal of Computer Integrated Manufacturing	1	4.76
Management Science Letters	1	4.76
Journal of Manufacturing Systems	1	4.76
IOP Conference Series: Materials Science and Engineering	1	4.76
Sustainability	2	9.52
Journal of Civil Engineering and Management	1	4.76
PLOS ONE	1	4.76

Figure 2 shows the number of articles collected by year of publication. Most of the articles found on this subject were published in 2022; i.e. four articles.

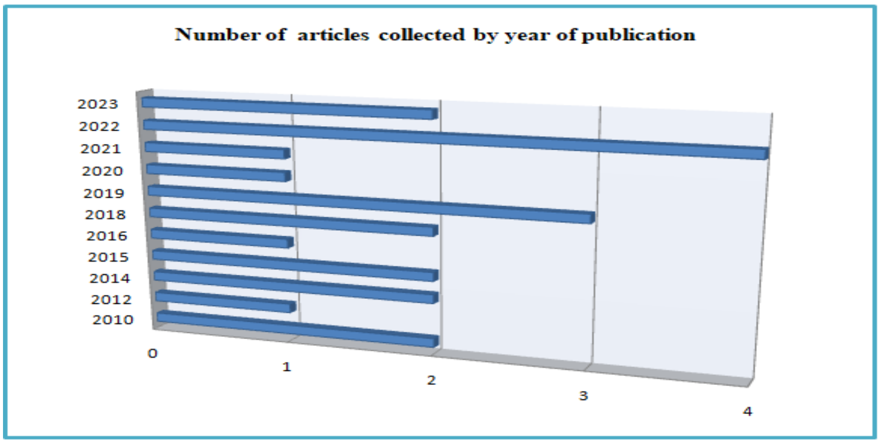

Fig. 2. Number of articles collected by year of publication

Three articles found were published in 2019, per two articles in 2010, 2014, 2015, 2018, and 2023. In the years 2012, 2016, 2020, and 2021, per one article.

Figure 3 shows the MCDM methods used in the articles. It is important to emphasize that the Analytic Hierarchy Process (AHP) method [1] and fuzzy AHP is the most used for solving the problem of evaluation of handling equipment in articles. After the AHP method, there are FUCOM (Full Consistency Method), WASPAS (Weighted Aggregated Sum Product Assessment), MOORA (Multi-Objective Optimization on the basis of Ratio Analysis), fuzzy TOPSIS (Technique for Order Performance by Similarity to Ideal Solution), and fuzzy VIKOR (VIšekriterijumsko Kompromisno Rangiranje) as a method that was used twice in the articles. Methods fuzzy FUCOM, fuzzy SWARA (Step Wise Weight Assessment Ratio Analysis), fuzzy BWM (Best Worst Method), R-method, WSA, fuzzy CODAS (Combinative Distance-based Assessment), EDAS (Evaluation based on Distance from Average Solution), fuzzy WA (Weighted Average), fuzzy MARCOS (Measurement of Alternatives and Ranking according to the Compromise Solution), TETE, PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations), fuzzy PROMETHEE, fuzzy FARE (Fuzzy Analytic Hierarchy Process and Regret theory), fuzzy ANP (Analytic Network Process), fuzzy BM (Borda count method), rough SWARA-ARAS, integrated CRITIC-MARCOS, fuzzy COBRA (Combined Objective Ratio Analysis), fuzzy ARAS (Additive Ratio Assessment) were used once each in the analyzed articles.

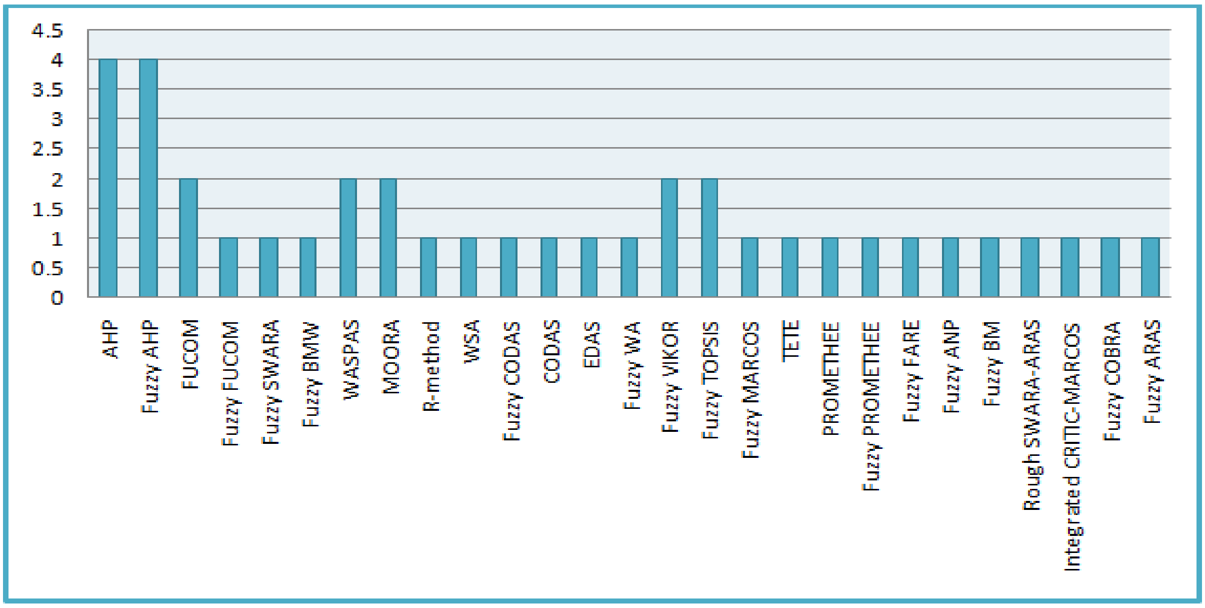

Fig. 3. MCDM methods used in articles to solve the problem of evaluation of handling equipment in logistics

Table 2 shows the percentages of handling equipment that was analyzed and used most in the articles collected. We see that the conveyor was taken the most times as an example for evaluation and decision-making by applying MCDM methods, seven times, which is 17.50 %. Conveyors are devices for transporting loads along a certain path, in the form of an endless belt, a series of rollers, chain elements, etc. It serves for the transfer, loading, and unloading of piece and bulk cargo in transport facilities, most often horizontally or under some slope, and less often vertically. With the conveyor system, it is possible to transport cargo from a greater distance. The next devices are cranes with 12.50 %, as well as forklifts. By cranes, we mean massive devices that are intended for the transfer and lifting of loads. They represent the most common type of machines for vertical transport and load transfer. In the articles, MCDM methods were especially used to select RMG or RTG cranes. RTG cranes (rubber tired gantry cranes, also called transtainers) are mobile gantry cranes used in intermodal operations for grounding or stacking containers. Intermodal operations mean that these containers can be used in different modes of transport, from road, and rail to trucks, without unloading and reloading their cargo. RMG cranes have a path on which they move and cannot change direction. Then, the devices listed by the number of their appearance in the articles are reach stackers, automatically guided vehicles (AGVs), and autonomous mobile robots (AMRs).

Table 2
Percentages of handling equipment used in the articles

Handling equipment in logistics	Percentages (%)
Front lift tractor	2.50
Reach stacker	10.0
Stacker	2.50
Side loader	2.50
Self-loading trailer	2.50
Straddle carrier	2.50
Automatically guided vehicle	7.50
Autonomous mobile robot	5.0
PDA with a built-in barcode scanner	2.50
Forklift	12.50
Electric forklift	2.50
Conveyor	17.50
Wheel loader	2.50
Excavator	2.50
Crane	12.50
Electric pallet truck	2.50
Industrial truck	2.50
Truck	2.50
GTP	2.50
VAV	2.50

2.2 Research Results

All collected articles on the subject of the application of MCDM methods for the evaluation of handling equipment in logistics are classified into four categories (Figure 4): intermodal transport, storage systems, logistics centers, and industrial logistics. It is important to note that some fields of logistics were not considered due to the lack of articles related to this subject.

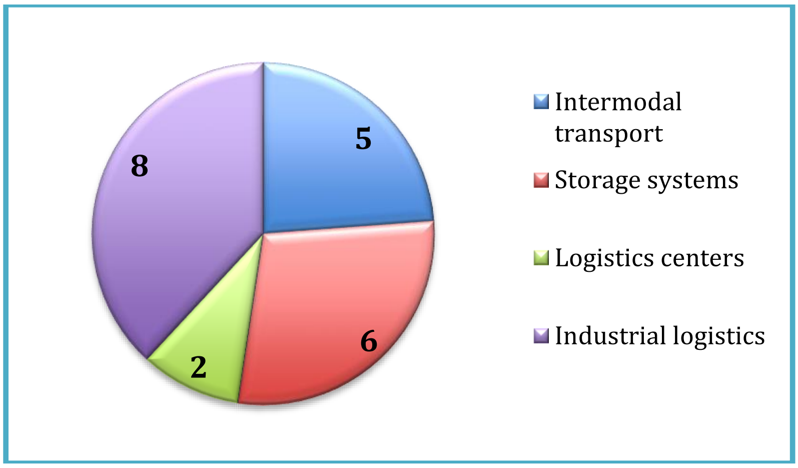

Fig. 4. Division of research papers into four areas

3. Intermodal Transport

Krstić *et al.* [2] solved the case study of selecting an appropriate handling tool for the planned intermodal terminal in Belgrade using a novel hybrid model that combines the fuzzy FSWARA and fuzzy best-worst method (FBWM). An intermodal terminal may contain a variety of handling equipment. For this study, the following handling equipment was chosen: front lift tractor, side loader, reach truck/stacker, self-loading trailer, and straddle carrier. Likewise, the determination of hardware was made based on 15 attributes: C_1-efficiency, C_2-load limit, C_3-speed, C_4-load lifting level, C_5-required control region, C_6-price tag, C_7-upkeep costs, C_8-lifetime, C_9-functional expenses, C_{10}-terminal plan costs, C_{11}-relevance, C_{12}-incorporation with different advancements, C_{13}-need for arranging and association, C_{14}-process automation possibility, and C_{15}-required preparing for working. The criteria for evaluating potential handling equipment were weighted using the FSWARA method, and the alternatives, or potential handling equipment, were evaluated using the FBWM method for the final ranking and selection of the most favorable one about the considered criteria. After the estimation, the truck/stacker was chosen as the most reasonable.

Dalalah *et al.* [3] applied the AHP method to the selection of cranes. The three alternative cranes that were the objects of the decision are the tower crane, Derrick crane, and mobile crane. After the calculations, the tower crane was identified as the best in this category and for the given conditions. After that, a detailed sensitivity analysis was held, and it showed that the choice of the crane remains the same even with significant changes in the weights of the criteria.

Stoilova and Martinov [4] proposed a methodology centered on the amalgamation of MCDM techniques for the assortment of transshipment machinery in a rail-road container terminal. The different variations of the handling machinery have been identified. Three categories of container handling machinery - electric rail-mounted gantry crane (RMG), diesel-powered rubber tired gantry crane (RTG), and mobile reach stacker (RS) were taken into account. The article employed a technical, economical, technological, and ecological (TETE) analysis. Sub-criteria were established for each primary TETE category to assess alternatives. The evaluation of alternatives involved 20 sub-criteria. The determination of weights for both the primary criteria and the sub-criteria was accomplished using the AHP technique. The PROMETHEE approach was employed to rank the alternatives. The sub-criteria that exert the most significant impact on the selection of an alternative encompass procurement expenses (11 %), yearly operating expenses (9 %), stacking capability (9 %), yearly equipment maintenance expenses (6 %), adaptability (6 %), and carbon dioxide emissions (6 %). The outcomes were validated through the utilization of TOPSIS. It was discovered that the RS represents a suitable choice for minor rail-road terminals, while the RMG emerges as the optimal option for medium and large rail terminals.

Krstić *et al.* [5] elucidated the choice of technology for intermodal terminal subsystems using an integrated fuzzy MCDM model. To address the defined issue, the article presents an inventive hybrid MCDM model that merges the fuzzy factor relationship (FFARE) and the fuzzy combinative distance-based assessment (FCODAS) methods. The FFARE technique is employed to determine the criteria weights, while the FCODAS method is employed for evaluation and final ranking of the alternatives. The investigation outlines 12 potential variations of handling machinery based on their techno-operational characteristics and assesses them against 16 criteria. The outcomes indicate that the most favorable handling technology variant entails the utilization of a rail-mounted gantry crane for handling tasks and a reach stacker for horizontal transport and storage. Furthermore, the results suggest that rather than selecting equipment for each process individually, it is crucial to consider a blend of diverse handling technologies that can collaborate to complete a series of handling cycle operations. This article presented a notable contribution by introducing a novel hybrid model and establishing a framework for the selection of appropriate IT subsystem technologies, along with a distinctive set of criteria for their evaluation and choice.

Stević *et al.* [6] identified the requirements of the IRT Belgrade container terminal. In this publication, an appropriate fuzzy group MCDM model was established by integrating fuzzy FUCOM, fuzzy MARCOS, and the fuzzy Bonferroni mean (BM) operator. A total of 15 criteria were formulated and categorized into three primary groups: economical, technological, and technical, which were assessed based on the input of 18 experts. To ascertain the weight values of the criteria, the fuzzy FUCOM method was applied using a total of 72 models, which were averaged using the Fuzzy BM operator. The evaluation and selection of the reach stacker were performed utilizing the fuzzy MARCOS method and the fuzzy BM operator. The technological group emerged as the most crucial set of criteria in group decision-making and processing of an extensive dataset. The best-identified choice was the seventh variation, which satisfied the requirement of selecting RS for the container terminal.

4. Storage Systems

Fazlollahtabar *et al.* [7] gave an overview of the warehouse system and talked about how important it is as a way to change the flow of goods over time in the larger logistics chain. The efficiency of transportation and handling operations is crucial to the warehouse system's effectiveness. The FUCOM-WASPAS model was the focus of the article. They examined the evaluation and selection of side-loading forklifts. The FUCOM strategy was utilized to decide the weight upsides of the measures, while the WASPAS approach was utilized for the assessment and positioning of the forklifts. Based on the requirements of "Euro-Roal," Doboj Jug, experts and employees in charge of mechanization maintenance provided the weightings for the selected criteria. The assessment thought about seven models: price tag, age, working hours, most extreme burden limit, greatest lifting level, biological variables, and accessibility of extra parts. Ten forklifts were considered as alternatives in this instance. The BAUMANN EHX 30/14/51 forklift, specifically, was found to be compatible with Euro-Roal's current requirements following the calculations.

Chakraborty and Saha [8] introduced FUCOM under the neutrosophic theory. Linguistic assessments by experts were considered as SVTNNs, and criteria weights were calculated using the proposed novel SVTNFUCOM. To achieve this, a novel SVTNLPP and a novel scoring function were introduced. Alternatives were ranked using MOORA. The study was conducted in a company that primarily coped with the trade and distribution of aluminum profiles. The model enabled an objective consideration of input parameters that influence the final decision. A key advantage of the proposed integrated strategy is that it allows warehouse system managers to make more decisions to improve the overall efficiency of the warehouse system. Using this model, it was possible to easily evaluate the efficiency of both forklifts and other equipment, as well as pay more attention to identifying and tracking input and output characteristics using this model.

Kučera [9] described the selection of warehouse handling equipment using MCDM. AHP and WSA methods were used in the study. The selection of suitable warehouse handling equipment was based on the number of pallets, the position behind the steering wheel, the battery, speed, load capacity, and maneuverability. The article used the WS method, where alternatives were assigned numbers according to the order of individual characteristics, with the highest sequence number having the highest alternative number. The Jungheinrich electric pallet truck proved to be the best by calculation, but it lacked size and maneuverability. This electric pallet truck was only suitable for transport on long and straight tracks. The Jungheinrich ESE 533 was selected according to multi-criteria decision-making.

In the article by Huskanović and Stević [10], the warehousing system of the Natron-Hayatcompany was analyzed. The objective CRITIC (Criteria Importance Through Intercriteria Correlation) method was used to determine the significance of the criteria, while the MARCOS method was used to evaluate and select the most favorable forklift. By analyzing the collected data using the MARCOS method, a ranking of the alternatives was obtained. The obtained results were verified by a sensitivity analysis that included changes in weight criteria, as well as a comparative analysis with other methods of MCDM. In the next phase of the article, the efficiency of transport and handling equipment in the company's warehousing system was calculated, and the DEA method was applied to determine the efficiency of a total of eight forklifts operating in the Natron Hayat warehousing system. After determining which forklift was the most efficient in the warehousing system, the procurement of an additional forklift was started according to the needs and appropriate criteria in the warehousing system. An integrated CRITIC-MARCOS model was used to analyze the collected data. The article analyzes nine criteria that are of great importance when buying a forklift. Then, the criteria and alternatives for selecting a forklift were defined, and four forklifts were analyzed as potential alternatives. Finally, the TOYOTA 8FBMT forklift was found to be the most affordable alternative.

Tuzkaya *et al.* [11] investigated the application of the methodology for the selection of industrial trucks in a manufacturing company for storage methodologies, which were producing agricultural machines, especially tractors. The focus was on the selection of industrial trucks for the company's warehouse located in Istanbul. The article used a methodology that considered four criteria: operational, economic, environmental, and strategic. Each criterion had its sub-criteria and their weights were determined using multiple steps, such as comparing the linguistic preferences of the decision-making team and calculating the weights of criteria. After the weights of the criteria were determined, the evaluation of alternatives was carried out using the F-ANP (fuzzy Analytic Network Process) and F-PROMETHEE methods.

Voćkić *et al.* [12] presented the rough SWARA-ARAS model for evaluating and selecting electric forklifts for warehouse operations. Based on the results of the applied model, a solution that met the needs of the Ekomed company was found; i.e., the Still RX 60-35 forklift. The results showed that the fourth criterion (i.e., maximum lift capacity) was the most important and that this criterion could have the greatest influence when deciding on the selection of a forklift.

5. Logistics Centers

In the article by Tadić *et al.* [13], the ranking and selection of smart MHE (material handling equipment) solutions were performed in logistics centers where deliveries were prepared for the supply of the urban area. This article proposed four smart solutions for a real company, and fourteen criteria were selected for the evaluation. A novel hybrid multi-criteria decision-making model that combined the fuzzy AHP method, which was used to determine the weights of the criteria, and the fuzzy COBRA method, which was used to rank the alternatives, was proposed. The application of the model showed that the best alternative was the implementation of an autonomous forklift, which could greatly automate logistics activities and reduced the rate of delivery errors.

Pamučar and Ćirović [14] presented the utilization of the new DEMATEL-MABAC model for the procurement of forklifts in coordinated operations habitats. In the exploration, the DEMATEL strategy was utilized to get the weight coefficients. An examination of the relevant literature served as the foundation for the selection of the criteria for the evaluation of forklifts. Using the MABAC (Multi-Attributive Border Approximation area Comparison) method, forklifts were evaluated and chosen. The SAW, COPRAS, TOPSIS, MOORA, and VIKOR methods were also put through their paces in the research under the same circumstances. Through the examination, the pragmatic application and awareness investigation of the MABAC strategy were introduced.

6. Industrial Logistics

The conveyors utilized in flexible manufacturing cells (FMCs) play a critical role in enhancing performance. The process of selecting conveyors involves the assessment of a range of potential alternatives based on qualitative and quantitative criteria. Nguyen *et al.* [15] presented an integrated MCDM model that combines fuzzy AHP and fuzzy ARAS for the evaluation and selection of conveyors. This model employed linguistic terms represented as triangular fuzzy numbers. The fuzzy set was incorporated into AHP to determine the weights of the criteria, while the fuzzy ARAS was employed to calculate the weights of the alternatives. To showcase the effectiveness of the proposed model, a case study was conducted using a practical example. The obtained results demonstrated the practical potential for FMC implementation. In this case study, experts evaluated and selected the conveyor alternative using the integrated framework. Specifically, fuzzy numbers were employed to convert qualitative information into precise data, and the steps of fuzzy AHP were utilized to determine the weights of criteria and sub-criteria while considering data consistency. Fuzzy ARAS was applied to rank the alternatives and reduce the pairwise comparison matrix between alternatives and fuzzy AHP when dealing with a large number of alternatives. This integrated approach effectively handled uncertain information and facilitated the final selection of the most suitable conveyor alternative. Consequently, by combining the strengths of fuzzy AHP and fuzzy ARAS, this approach required less computational power, as well as enabled faster and more accurate decision-making.

A model for selecting handling equipment that was based on two fuzzy multi-criteria decision-making techniques was incorporated into the study by Chamzini [16]. The AHP and TOPSIS approaches, group decision-making, and fuzzy set theory all contribute to the proposed evaluation model. The fuzzy AHP strategy was utilized to ascertain the overall significance of the assessment standards. Fuzzy TOPSIS was applied to assess the worth. A truck, a belt conveyor system, and a truck-in-pit crusher-belt conveyor system were the three considered options. A dynamic gathering comprising 10 specialists recognized significant standards like capital expense (C_1), activity cost (C_2), creation (C_3), material size (C_4), ground condition (C_5), distance (C_6), weather patterns (C_7), climate (C_8), risk (C_9), unwavering quality (C_{10}), proficiency (C_{11}), accessibility (C_{12}), wellbeing (C_{13}), adaptability (C_{14}), and valuable life (C_{15}). These 15 attributes were characterized into three fundamental standards, including monetary boundaries, working boundaries, and specialized boundaries. The model was applied to a certifiable contextual investigation to exhibit the capacity and viability of the proposed model. In the end, a sensitivity analysis was done to see how sensitive the results were to changes in the weights of the criteria. The truck-based alternative was the best option.

Mathew and Sahu [17] investigated the problem of selecting appropriate material handling equipment, especially for transporting loads from one place to another. They solved two problems of material handling equipment selection using different MCDM methods. First, the problem of selecting conveyors with six conflicting criteria and four alternatives was solved using four MCDM methods: CODAS, EDAS, WASPAS, and MOORA. Another problem that was solved was the selection of AGVs with six conflicting criteria and eight alternatives, also using CODAS, EDAS, WASPAS, and MOORA methods. Spearman's rank correlation coefficient was calculated between the ranks obtained by different methods. CODAS, EDAS, WASPAS, and MOORA methods were used to select conveyors, and the same methods were also used to select AGVs.

Mousavi *et al.* [18] focused on the utilization of linguistic terms characterized by trapezoidal fuzzy numbers to determine the weights of selected criteria. They also assessed the performance of alternatives concerning conflicting criteria. A gray relational analysis approach was then employed to explore the level of relationships between two alternatives by employing effective fuzzy distance measurement in a group decision-making setting. Furthermore, a novel ranking index was developed to achieve a compromise solution and identify the best alternative for addressing complex decision-making problems. The article also presented a practical example that applied this method to the problem of material handling equipment selection, showcasing the feasibility and applicability of the proposed ranking process. A comparative analysis was conducted between the proposed method and the combined VIKOR method. The article also dealt with an example related to a textile manufacturing company that wanted to rank and select the appropriate equipment for material handling among four candidates. Different characteristics and multiple conflicting criteria were considered. A board of three professional decision-makers evaluated potential alternatives according to six criteria related to utility and cost. The importance of the criteria was considered, and the hierarchical structure of the decision-making problem was presented.

Vencheh and Mohamadghasemi [19] dealt with the problem of material handling equipment selection in manufacturing or service systems. The decision to select appropriate material handling equipment often has involved evaluating a finite number of alternatives based on various qualitative or quantitative criteria or sub-criteria. Many researchers used MCDM to solve this problem. The first step in the methodology was to use voting to assign weights to criteria and sub-criteria. Experts rated the importance of each criterion and sub-criteria using scales such as very low importance, low importance, moderate importance, high importance, and very high importance. After assigning the weights, the synthetic value estimation method was used to convert the ratings expressed as linguistic variables for each alternative into a single fuzzy weight. The fuzzy weighted average method was then applied to aggregate the single fuzzy weights of each alternative related to the sub-criteria within each criterion. Finally, the fuzzy multi-criteria optimization and compromise solution method was used to select the optimal material handling equipment.

Chatterjee and Chakraborty [20] focused on solving the problem of selecting appropriate material handling equipment in industrial sectors. Selecting the right material handling equipment is extremely important for increasing the efficiency of production processes. However, as the number of alternatives available on the market and the complexity of the evaluation criteria increase, the selection of appropriate equipment becomes more and more challenging. For this purpose, the researchers introduced a novel MCDM technique called the R method. The R method was applied to five material handling equipment selection problems including conveyors, AGVs, stackers, wheel loaders, and excavators. The research results showed that the R method is an effective MCDM strategy for solving the problem of material handling equipment selection. Through the application of the R method, the researchers were able to identify the most desirable option in each of the equipment selection problems.

Buyukozkan *et al.* [21] discussed the evaluation of mobile logistics tools in the context of efficient logistics and supply chain management. The aim was to help decision-makers identify the most appropriate mobile logistics tools. The evaluation process included two phases: pre-assessment and selection. In the first phase, alternatives that do not meet basic requirements and defined thresholds were eliminated. In the selection phase, the remaining alternatives were evaluated in more detail. The evaluation criteria were determined using the AHP method in which the phase of axiomatic design (FAD) was used. Then, the TOPSIS method was applied to compare the results. The article presented a case study focusing on the evaluation of personal digital assistants (PDAs) with integrated barcode scanners available on the Turkish market. The study demonstrated the potential of the proposed methodology for evaluating mobile logistics tools and provided a framework for decision-making in this area. This study was valuable since it filled a gap in the literature related to the evaluation of IT tools, especially mobile logistics tools such as PDAs and barcode scanners. The methodology was validated through a case study in the Turkish logistics industry. The authors suggested further research that might include additional case studies and evaluation of other tools such as RFID systems using the proposed methodology.

Hornakova *et al.* [22] explored handling equipment that could be used in a specific industrial company to transport and handle finished goods. Specific calculations were carried out in the Expert Choice program and the AHP method was utilized to assist in the decision-making process regarding the appropriate handling equipment. AGVs were chosen as the most satisfactory arrangement.

7. Conclusions

This review paper focused on the application of MCDM methods in the evaluation of handling equipment in logistics. Through a review of 21 research papers published from 2010 to date, various MCDM methods and their application in the selection of equipment such as forklifts, cranes, conveyors, AGVs, AMRs, reach stackers, etc. have been investigated. These devices were used in a variety of logistics contexts, including warehouses, ports, city logistics, and intermodal transport. Research results published in various journals were analyzed. The research papers considered MCDM methods such as AHP, MABAC, SWARA, ARAS, FUCOM, CRITIC, and MARCOS, as well as various fuzzy methods. This review demonstrated that the field of research on the application of MCDM methods in the evaluation of handling equipment in logistics is important and of current interest.

The role of handling equipment in the logistics sector is extremely important. Efficient handling of this equipment is key to optimizing logistics processes, reducing costs, and increasing productivity. However, selecting the right equipment can be a challenge due to the variety of options on the market. It is in such situations that MCDM methods come to the fore. In the context of logistics handling equipment evaluation, these methods allow the evaluation and ranking of alternatives based on various criteria such as price, reliability, performance, adaptability, safety, etc. MCDM methods enable the analysis of all those criteria as a whole, taking into account their interrelationship and significance. The application of MCDM methods in the evaluation of handling equipment in logistics can lead to a better understanding of the advantages and disadvantages of different options. This facilitates making the right decisions that will result in optimal equipment handling, cost reduction, and increased efficiency of logistics processes. Therefore, the application of MCDM methods represents an important and useful approach for improving the operations of logistics companies.

According to the finding, conveyors were the most frequently used example for evaluation and decision-making using MCDM methods, followed by cranes and forklifts. Taking into account the growing significance of logistics and the need for efficient equipment handling, the application of MCDM methods can provide a valuable tool for the decision-making and optimization of logistics processes.

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