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DECISION-MAKING IN TRANSPORT AND LOGISTICS USING INTEGRATED MODELS

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Abstract

Everyday decision making requires consideration of various influencing factors. Important tools for solving and supporting such problems are MCDM models, most often in combination with uncertainty theory or other approaches. The aim of this paper is to emphasize the rapid development of this field and its importance for solving professional problems showed on examples in field of transportat and logistics. The significance of such integrated models has been manifested through few examples in which the MCDM methods (FUCOM, MARCOS, Fuzzy PIPRECIA, Fuzzy FUCOM, Fuzzy EDAS) have integrated with other approaches such is SERVQUAL model, Delphi method, SWOT/TOWS analysis, DEA, PCA, ABC analysis. These integrated approaches can be useful for decision-making because it can helps: to reduce costs in company, to increase quality of logistics services, to have possibility for determination the quality and efficiency of the company, to chose the best strategy for own business, to clearly shows which road to choose, to be applicable in small and medium enterprises (SMEs) that make these and similar decisions, to can adjust their business policies to the results of the model and achieve better business results.

Key words*: decision-making, transport, logistics, integrated model*

1 INTRODUCTION

In today's modern society, constant progress is required, both from a scientific and professional characterEvery day the question is how to improve something, how to rationalize, how to increase efficiency, which methodology to apply, etc.? Transport and logistics, whether viewed separately or together, represent examples of areas where daily improvement is needed. Due to its comprehensiveness, logistics in one way includes transport, which, according to most authors, is one of the basic logistics subsystems. As such filed, logistics requires constant application, but also the development of new approaches that will contribute to the overall optimization of its processes and activities. Since many individual tools cannot adequately respond to the set needs and requirements, integrated models are created. Such models use the advantages of individual methods and approaches in some phases of rationalization and optimization. In this way, adequate decision-making and increased efficiency are achieved.

The aim of this paper is to present different methods and approaches that have been integrated into original models in the previous three years and applied in the field of transport and logistics. The presented models refer to decision-making in transport, storage systems, and when performing operations in the transshipment subsystem.

The paper is structured through a total of four chapters. In addition to the introductory remarks presented in the first chapter, a brief overview of the specific methods and approaches integrated into the second chapter is given. An essential part of the paper is the third chapter, which briefly presents the results of the application of various integrated models. Examples are given: making decisions related to the implementation of strategies in the transport company, measuring the efficiency of forklifts in the warehousing system of the production company, determining the conditions for implementing information technology in the warehousing system, classification of stocks in the warehousing system, determining quality in reverse logistics and company of express delivery. The fourth chapter summarizes the results of this brief review.

2 METHODS

This part of the paper presents the methods and approaches that are the subject of this review paper. Figure 1 shows the complete structure of the methodology, which is broken down according to the applicability criteria.

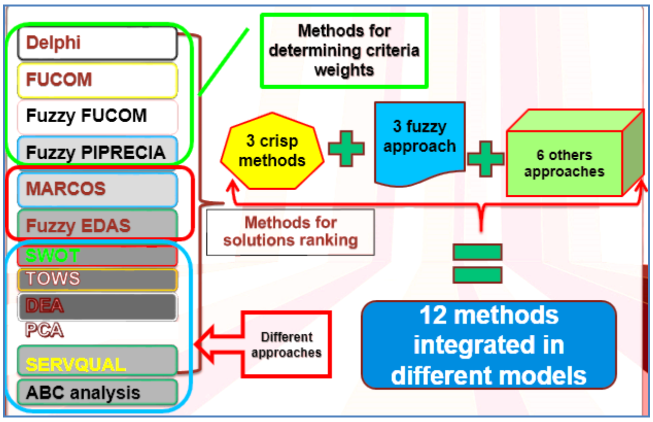

Fig. 1. Integration of different methods and approaches

Figure 1 shows a total of 12 methods and approaches that are integrated into different models. First, the multi-criteria decision-making (MCDM) methods are presented, and which belong to methods for determining the criteria weights. Those are Delphi, FUCOM (FUll COonsistency Method) [1], fuzzy form of that method and fuzzy PIPRECIA (PIvot Pairwise RElative Criteria Importance Assessment) [2]. Then, the MCDM methods used to rank variant solutions are presented: MARCOS (Measurement of alternatives and ranking according to COmpromise solution) [3] and fuzzy EDAS (Evaluation based on Distance from Average Solution) [4]. In addition, these methods are integrated with several other approaches: SWOT (Strengths, Weaknesses, Opportunities and Threats), [5] TOWS (Threats, Opportunities, Weaknesses and Strengths) [5], DEA (Data Envelopment Analysis) [6,7], PCA (principal component analysis) [8] and SERVQUAL (Service quality) model [9,10,11]. Thus, an overview of a total of 12 different methods is given.

3 INTEGRATED MODELS

This part of the paper presents examples of creating different models through the integration of previously presented methods and approaches.

3.1. Integration of Fuzzy PIPRECIA, FUCOM, MARCOS methods with SWOT/TOWS analysis in transport

In this example [5,12] the integration of several methods into one original model for decision making in the field of transport is shown. Figure 2 shows the complete research flow and integration of different methods into the original model.

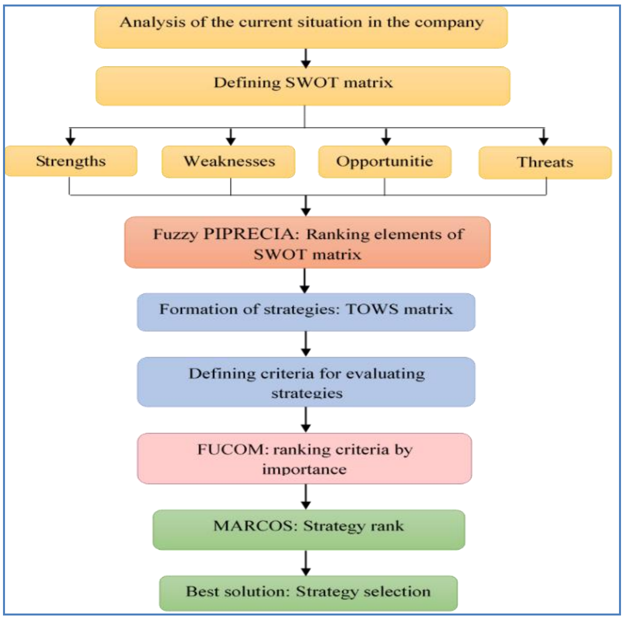

Fig. 2. *Integration of fuzzy PIPRECIA, FUCOM, MARCOS methods with SWOT/TOWS*

The first phase represents data collection from a particular transport company. It describes the current situation in the transport company and determines its internal strengths and weaknesses as well as external opportunities and threats. The data is the basis for the SWOT analysis. After this in the second phase, the Fuzzy PIPRECIA method ranked elements of the SWOT. The third phase, the cross-SWOT analysis helps to form the TOWS matrix and to define strategies for transport company. This phase defines the criteria to evaluate the strategies. The FUCOM method helps to rank the criteria in descending order of importance and finally to assess their significance in the fourth phase. The MARCOS approach helps to evaluate strategies in the fifth stage. [12]

After completing the SWOT analysis and applying the fuzzy PIPRECIA method for determining the weights of all its elements, the results presented in Figure 3 were obtained.

INTERNAL FACTORS					
STRENGTHS (+)	Value	Rank	WEAKNESSES (-)	Value	Rank
1. Modern trucks and the ability to respond to all requests	0.103	1	1. Disloyalty of employee s	0.068	3
2. Worker motivation	0.048	9	2. Workers' omissions (information of exponents, etc.)	0.033	18
3. Professional employees and years of experience	0.051	8	3. Close relationship in communication between owner and worker	0.040	15
4. Offices in EU and organization and responsibility (family business)	0.058	4	4. Cost optimization	0.058	5
			5. Absence of test moves (employee evaluations)	0.047	10
5. Recognition by brand	0.070	2	6. Need for one administrative worker	0.039	16
6. Cost optimization	0.041	14			
EXTERNAL FACTORS					
OPPORTUNITIES (+)	Value	Rank	THREATS (-)	Value	Rank
1. Expanding business	0.053	7	1. Closing other companies	0.045	12
2. Infrastructure growth	0.031	21	2. Growth of levies	0.046	11
3. Association	0.044	13	3. Unexpected problems from the ground	0.027	23
4. EU funds	0.030	22			
5. Training course through Eco trainings	0.037	17	4. Unloyal competition	0.033	19
			5. EU restrictions (CEMT, etc.)	0.032	20
			6. Fluctuation of labor	0.055	6

Fig. 3. *Results of Integration of fuzzy PIPRECIA and SWOT analysis*

Figure 3 shows the elements ranked by importance. First, the ranking of strengths, weaknesses, opportunities and threats as a group of elements was performed. In this case, strengths have the highest value (0,337), that means that the strengths are ranked first by importance. Weaknesses are in second place (0.274), while threats (0.231) and opportunities (0.188) are in third and fourth place respectively. Therefore, strengths and weaknesses are more important for a company as internal factors with influence on its business than external factors, ie opportunities and threats. The results shows that the first element - a modern trucks and the ability to respond to all requests is ranked as the first element. Second by importance is brand recognition, an element that, like the first, is in the group of elements that make the strengths of the company. The lowest ranked element in this group is cost optimization, and in the overall ranking of the elements it takes 14th place.

The worst ranked element in this group is workers' failures, while it takes 18th place in the overall ranking of the elements. The highest ranking element from the group of elements that make opportunities from the environment of the company is business expansion, and in the overall ranking of all elements it takes 7th place. The worst ranked element in this group is EU funds, and it takes 22nd place in the overall ranking. Within the group of elements that make threats from the environment, the highest ranked element is fluctuation of labor, and the worst ranked element is unexpected problems from the ground, which also takes the worst 23rd position in the overall ranking of the elements. [12]

The TOWS matrix formed after the ranking of the criteria represents the business strategies of the transport company. Figure 4 shows the strategies (TOWS matrix) created by the cross-SWOT analysis.

Strategy SO	Strategy WO
1. Expanding business based on years of experience and brand. 2. Applying for European funds based on responsibility, organisation and professionalism. 3. Association with other transport companies using business on the territory of the EU.	1. Cost rationalisation through eco-trainings. 2. Increasing loyalty of employees by creating a driver evaluation and reward model. 3. Increasing the productivity of disponents by hiring one administrative worker.
Strategy ST	**Strategy WT**
1. Fight against unfair competition using advantage of modernisation and quality. 2. Reducing fluctuation of workers using advantage of motivation. 3. Reducing levies using the strengths and benefits of association.	1. Easier problems solving on the ground by improving communication between workers and management. 2. Faster problem solving by reducing closeness and intimacy between owner and worker. 3. Increasing the volume of domestic transport using the benefits of infrastructure growth and development.

Fig. 4. *TOWS matrix which represent strategies for transport company*

The previously defined strategies are the basis to assess the general strategy of the transport company's development: [5]

1. Expanding business based on years of experience and brand,
2. Applying for European funds,
3. Cost rationalisation,
4. Driver evaluation and rewards program,
5. Increasing the volume of domestic transport using the benefits of infrastructure growth and development.

The following criteria (Fig. 5) set was the basis to evaluate the strategies.

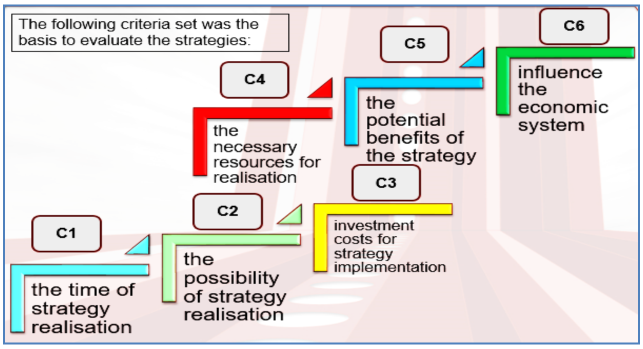

Fig. 5. *Criteria for evaluation of strategies*

After applying the FUCOM method to determine the criteria weights presented in Figure 5, the following results were obtained: C1=0.170, C2=0.196, C3=0.255, C4=0.128, C5=0.134, C6=0.116. The most important criterion is the investment costs required to implement a particular strategy. After that, the MARCOS method was applied, which shows that the fourth strategy driver evaluation and rewards program is the closest to the current realization.

A TOWS matrix was formed based on the cross SWOT matrix. In this way, the business strategies of the transport company are determined, among which the management should choose the best one. During the study, the authors developed a decision model. The results show that the best strategy that the transport company can choose at this moment is A4 - Driver Valuation and Reward Program, whose value of the utility function equals to 0.716. This strategy does not involve the engagement of additional resources and does not require much time to implement. The worst-ranked plan is the A3 - Cost Rationalisation, whose value of the utility function equals to 0.405. According to these results, the management should establish a program to evaluate and reward drivers, to provide both rationalisation of costs and reduction of emissions in the operation of drivers. [5]

3.2. Integration of PCA, DEA, FUCOM and MARCOS methods for efficiency analysis of the forklifts in warehousing systems

In this example [7], the analysis of forklift efficiency was performed by integrating different approaches shown in Figure 6.

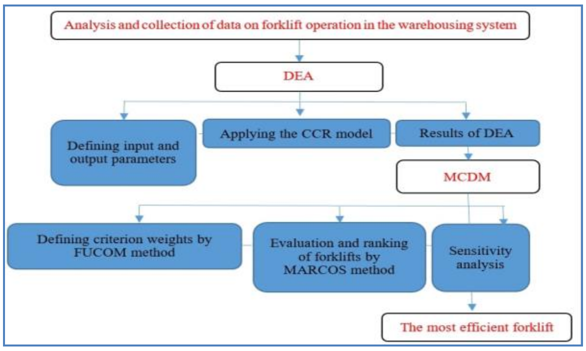

Fig. 6. *Integration of PCA, DEA, FUCOM and MARCOS methods for efficiency analysis of the forklifts*

Five input parameters (regular servicing costs, fuel costs, exceptional servicing costs, total number of all minor accidents and damage caused by forklifts) and one output parameter (number of operating hours) were first identified to assess efficiency of eight forklifts in a warehousing system. After application of DEA model forklifts 5, 6, 7 and 8 have values less than 1, and are not considered further into the model since they are not efficient enough and do not contribute to the warehouse system like other forklifts. It is observed that the first four forklifts have efficiency values of 1, indicating them as efficient alternatives and the most efficient of these four forklifts will now be selected in the next phase using FUCOM-MARCOS methods. [7]

According to the results of FUCOM method, can be concluded that out of five criteria, criterion related to fuel costs is the most significant (C2). It is then subsequently followed by criterion C5 (number of operating hours) and C1 (regular servicing costs). The last two and least significant criteria are the criteria relating to the total number of all minor accidents and damage caused by the forklift (C4) and exceptional servicing costs (C3). Results of MARCOS method show that the most efficient forklift is A1, i.e. alternative 1. From Table 7, it is observed that utility function of forklift A1 is significantly higher than the obtained values of other forklifts. Forklift A2 is less efficient as compared to the forklift A1, and the next position in terms of efficiency is occupied by forklift A3. The least efficient among these four forklifts is forklift A4, i.e. alternative 4 due to its lowest utility function value. [7]

PCA-DEA integration was performed in order to check the efficiency based on a smaller number of inputs thanks to the application of PCA.

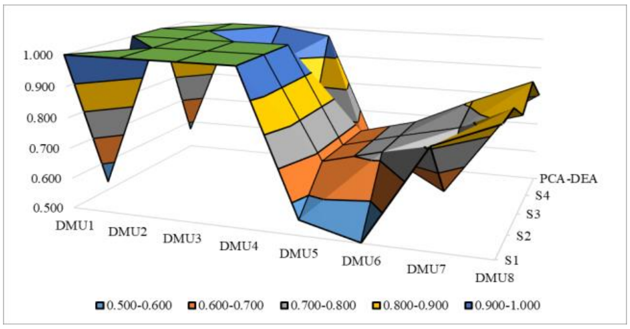

Fig. 7. *Results of application of PCA-DEA and reduced number of inputs*

By applying the PCA-DEA model (Fig. 7), the results the efficiency of forklifts V2-V4 does not change (1.000). In contrast, the efficiency of the first forklift V1 changes drastically because it gets inefficient and the lowest value.

3.3. Integration of SWOT and fuzzy PIPRECIA of Assessment of conditions for implementing information technology in a warehouse system

In this example [2], the original fuzzy PIPRECIA method was developed to evaluate the conditions for the implementation of barcode technology into the warehouse system. First, a SWOT analysis was defined based on the current situation and needs, which is shown in Figure 8.

STRENGTHS	WEAKNESSES
Human resources in the warehouse system	Difficulties in inventory control
A linked work system among the Weighing Scale, Reception Warehouse and the Warehouse of technical material	Difficulties in supplementing warehouse inventory
Good organization of the work unit	The problem with the way of confirming the material issued
Good relationship between warehouse keepers and users	The excessive period between taking materials out and their confirmation
All items are clearly marked and sorted throughout the warehouse (suspension cards)	Keeping records of debts
Warehouse work conditions	Wasting the warehouse keepers' time on material confirmation
	Consumption of office supplies when performing all warehouse activities
Access to the main road	Warehouse keepers' errors when recording materials
	Current IT system of work
OPPORTUNITIES	**THREATS**
Automatic inventory control	Employer's lack of understanding of the importance to introduce a barcode
Faster supplementing of monthly warehouse inventory	Users' lack of understanding of the importance to keep the warehouse using a barcode system
Faster confirmation of goods by users	The warehouse keepers' lack of understanding of the importance to introduce a barcode system into the warehouse
Eliminating faults when typing a requisition form	Provision of financial resources
Eliminating the waste time of warehouse keepers to keep records of debts	
Modernization of WU Warehouse operation	
Confidence between warehouse keepers and users	

Fig. 8. *SWOT analysis for implementing information technology in a warehouse system*

If the contribution from a practical aspect is observed, it can be emphasized that by assessing the conditions for the application of barcode technology in this part of the company, an adequate basis for increasing the efficiency of logistics operations is achieved. It is a company that has about one thousand employees and covers about one million square meters, including a large volume of exports and a large number of logistics operations and processes. [2]

3.4. Integration of Delphi, FUCOM and SERVQUAL for measuring quality of logistics company

Through the following example [9], an analysis of the quality of a logistics company dealing with fast delivery of goods was performed. The sample was conducted on 70 customers of legal and private structure. The Delphi method was first applied in integration with FUCOM to determine the significance of the five basic dimensions of the SERVQUAL model shown in Figure 9.

Order No.	Questions	
1.	The company will provide a service at the expected time.	reliability
2.	Employees in the company will show interest in customers' problems.	
3.	The company will provide a service as promised.	
4.	Delivery of the shipment will be carried out on the first attempt.	
5.	The company will reliably carry out delivery of large value shipment.	
6.	The company will deliver the shipment at the expected time for long distance.	
7.	Employees' conduct will create trust of customers.	assurance
8.	Customers will be safe while using services.	
9.	Senders/receivers will be informed if the service is not possible.	
10.	Couriers will pick up and/or deliver the shipment at the expected time.	
11.	The cost of the service will be acceptable.	tangibles
12.	Couriers in the company will be kind.	
13.	Company's delivery vehicles will be visually appealing.	
14.	Packaging of delivered shipment will be clean and neat.	
15.	Employees in the company will look neat.	
16.	Delivery vehicles will be modern and will have all necessary equipment.	
17.	Individual attention will be given to the customer.	empathy
18.	Customers will feel comfortable in contact with employees.	
19.	Employees in the company will show understanding.	
20.	The company will recognize the needs of customers.	
21.	The working hours of the company will be appropriate and acceptable to customers.	
22.	Employees in the company will be willing and able to help.	responsibility
23.	Customers will obtain right answers to their questions.	
24.	Employees at the Call Center will provide all necessary information to customers.	
25.	Upon request, customers will respond quickly and reliably.	

Fig. 9. *SERVQUAL survey for quality determining in logistics company*

As can be seen, the original SERVQUAL questionnaire was developed which involves 25 items through five basic dimensions. It is based on the difference between observations and expectations with the application of certain statistical tests. Applying Delphi and FUCOM method, the results showed: the final values of weight coefficients of the dimension of reliability (D1=0.291), assurance (D2=0.259), tangibles (D3=0.130), empathy (D4=0.109), and responsiveness (D5=0.207). The Cronbach alpha coefficient was also calculated, which shows that the reliability of the created SERVQUAL questionnaire is at a high level. Of course, the calculation process was performed specifically for expectations, and especially for observations, so that in the end their difference could be determined. The results of the application of the integrated Delphi-FUCOM-SERVQUAL model in a logistics company are shown in Figure 10.

Dimension	AV	SD	W_j	Cronbach Alpha Coefficient
Reliability	4.029	1.010	0.291	0.918
Assurance	4.100	1.022	0.259	0.891
Tangibles	4.150	0.924	0.130	0.845
Empathy	4.260	0.829	0.109	0.851
Responsiveness	4.282	0.831	0.207	0.875
SERVQUAL (1)	**4.164**	**0.923**	**1**	**0.876**

Dimension	AV	SD	W_j	Cronbach Alpha Coefficient
Reliability	4.176	0.995	0.291	0.947
Assurance	4.196	1.006	0.259	0.889
Tangibles	4.200	1.040	0.130	0.824
Empathy	4.360	0.844	0.109	0.891
Responsiveness	4.282	0.944	0.207	0.894
SERVQUAL (2)	**4.243**	**0.966**	**1**	**0.889**

Delphi-FUCOM-SERVQUAL			
Dimensions	PER	EXP	Gap
Reliability	1.172	1.215	0.043
Assurance	1.062	1.087	0.025
Tangibles	0.540	0.546	0.006
Empathy	0.464	0.475	0.011
Responsiveness	0.886	0.886	0.000
Total			0.017

Fig. 10. *Results of Delphi-FUCOM-SERVQUAL for quality determining in logistics company*

Generally, customers are satisfied with the quality of the logistics service of the express post company. For all dimensions except for the dimension of responsiveness, the result is positive. It can be noticed that the greatest satisfaction of customers was expressed for the dimension of reliability. [9]

3.5. Integration of Delphi, FUCOM and SERVQUAL for measuring quality of reverse logistics

The following study [10] presents a similar example of an integrated model applied in the field of reverse logistics. Of course, the created SERVQUAL questionnaire is different from the previous example and has a total of 21 items for expectations and observations (Figure 11).

Dimensions		Statements
Reliability	Q1	Services will be provided at the expected time
	Q2	Waste will be collected regularly
	Q3	Waste collection will be performed without difficulties
Assurance	Q4	Workers will be careful when performing work tasks
	Q5	The user will be informed in a timely manner
	Q6	The cost of the waste collection service will be fixed
Tangibles	Q7	The cost of the service will be acceptable
	Q8	No noise will be generated during waste collection
	Q9	Invoices will be clear and delivered to home addresses
	Q10	The streets will be clean and tidy
	Q11	The containers will be placed close to the household
	Q12	There will be no unpleasant odors at waste disposal sites
	Q13	Waste collection vehicles will be modern
Empathy	Q14	Services will be flexible and customized
	Q15	The time of waste collection and transport will be appropriate
	Q16	When charging, population categories will be taken into account
Responsiveness	Q17	Workers will be professional during the waste collection process
	Q18	Novelties will be accepted quickly
	Q19	Users' needs will be adequately responded to
	Q20	Waste collection will be fast and adequate
	Q21	Traffic will not be disturbed

Fig. 11. *SERVQUAL survey for quality determining of reverse logistics*

After applying Delphi and FUCOM methods the following results are obtained: The highest value was given to the responsiveness dimension (w=0.231), followed by the reliability dimension (w=0.211), assurance (w=0.197), tangibles (w=0.189), while the empathy dimension gained the least weight (w=0.172) [10]. Results of applied integrated model has shown on Figure 12.

Dimension	Expectations			Perception			SQ Gap
	AV	ST	CA	AV	ST	CA	
Reliability	3.848	1.230	0.845	3.783	1.189	0.813	−0.014
Assurance	3.915	1.234	0.746	3.385	1.269	0.600	−0.009
Tangibles	3.712	1.348	0.822	3.655	1.321	0.618	−0.017
Empathy	3.342	1.281	0.942	3.247	1.229	0.338	−0.018
Responsiveness	3.833	1.287	0.810	3.699	1.242	0.600	−0.029
SERVQUAL	3.730	1.276	0.833	3.554	1.250	0.600	−0.017

Fig. 12. *Results of Delphi-FUCOM-SERVQUAL for quality determining of reverse logistics*

The results of the applied methodology showed that the quality in the field of reverse logistics in the research territory is not adequate in any of the dimensions. Such indicators are worrying and call for urgent measures to improve quality.

3.6. Integration of Fuzzy FUCOM and ABC analysis for inventory classification

Adequate inventory classification is one of the prerequisites for managing products related to warehousing activities. ABC analysis is indispensable in all storage systems, but the purpose is to apply as often as possible on the basis of several criteria. Therefore, in the following example [13], the integration of fuzzy FUCOM [14] and ABC analysis was performed [15]. Figure 13 shows the research flow of this study.

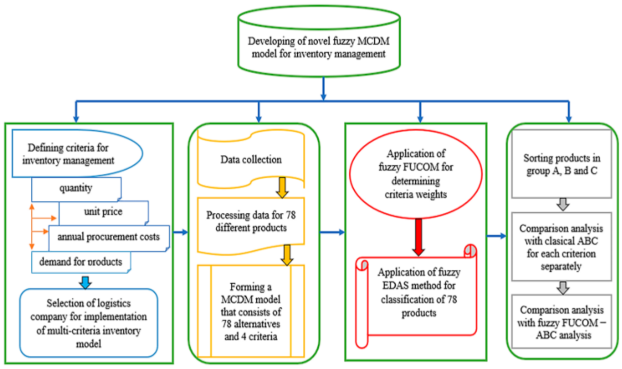

Fig. 13. *Research flow for inventory management*

It is important to note that the integration of fuzzy FUCOM and fuzzy EDAS methods for all purposes was created and a detailed presentation of the comparative analysis with the single-criteria ABC analysis is given in [13]. After the obtained results using fuzzy FUCOM and ABC analysis based on four criteria: quantity, unit price, annual procurement costs and demand for products, 19 products are classified in group A, 28 in group B, while 31 are classified in group C. A complete comparative analysis of different approaches with inventory classification is presented in Figure 14.

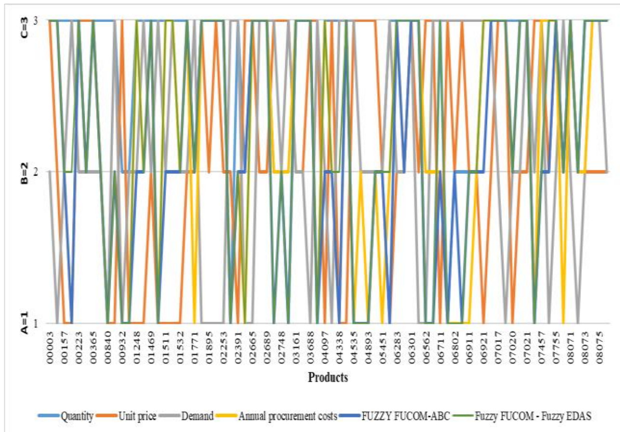

Fig. 14. *Comparative analysis of fuzzy FUCOM – ABC with other approaches*

In addition, the integration of the ABC-FUCOM-interval rough CoCoSo model was applied in another study [16] related to another warehouse system. In addition to inventory classification, the model has been successfully applied to select suppliers for each product group separately.

4 CONCLUSION

Through this paper, a brief overview of the author's own studies was performed, in which different approaches were integrated in order to obtain better results. The given examples refer to the transport and warehousing subsystem, as two basic logistics subsystems. In addition to the above, the application of integrated MCDM models that are applied in the field of logistics for various purposes is inevitable. The application of recent methods such as FUCOM and MARCOS is very popular. In a study [17], this combination was used to evaluate drivers in a transport company. The same integration was applied in [18] for the selection of the distribution channel of final products. Similar integrations were performed in [19].

These integrated approaches can be useful for decision-making because it can helps: to reduce costs in company, to increase quality of logistics services, to have possibility for determination the quality and efficiency of the company, to chose the best strategy for own business, to clearly shows which road to choose, to make right decisions for inventory management, to can adjust their business policies to the results of the model and achieve better business results.

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