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Original Article

A NEW METHODOLOGY FOR TREATING PROBLEMS IN THE FIELD OF TRAFFIC SAFETY: CASE STUDY OF LIBYAN CITIES

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Highlights:
- development of a new methodology for addressing traffic safety issues;
- utilization of an integrated MCDM model for ranking cities based on traffic safety;
- verification of model stability and results;
- high correlation of ranks demonstrated by SCC.

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Abstract. Traffic safety is an area of great importance, since there are many traffic accidents every day in which a significant number of people are killed. Defining certain strategies and identifying potentially the most dangerous towns and cities regarding this area are, on the one hand, a necessity, and, on the other hand, a challenge. In this paper, integrated Multi-Criteria Decision-Making (MCDM) model for ranking cities in Libya from the aspect of traffic safety has been proposed. The model implies a set of 8 criteria on the basis of which 5 decision-makers rated the 10 most deprived cities in Libya. The Full Consistency Model (FUCOM) in combination with the rough Dombi aggregator is used to determine the significance of the criteria. The Rough Simple Additive Weighting (R-SAW) method is used to rank the alternatives. The rough Dombi aggregator is also used for averaging in group decision-making while evaluating the alternatives. The stability of the model and the obtained results has been verified by the sensitivity analysis, which implies a 2-phase procedure. In the 1st phase, rough Additive Ratio Assessment (R-ARAS), Rough Weighted Aggregated Sum Product Assessment (R-WASPAS), Rough Complex Proportional Assessment (R-COPRAS) and Rough Multi-Attributive Border Approximation-area Comparison (R-MABAC) methods are applied. The 2nd phase implies changing the parameter ρ in the procedure of rough Dombi aggregator, while the 3rd phase includes the calculation of Spearman's Correlation Coefficient (SCC) that shows a high correlation of ranks.

Keywords: FUCOM, traffic safety, R-SAW, MCDM, rough Dombi aggregator, traffic accidents.

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Notations

AADT – annual average daily traffic;
AHP – analytic hierarchy process;
ARAS – additive ratio assessment;
BMW – best worst method;
CBD – central business district;
COPRAS – complex proportional assessment;
F-BEM – fuzzy-based evaluation method;
FUCOM – full consistency model;
ELECTRE – elimination and choice translating reality (acronym from French: *ELimination Et Choix Traduisant la REalité*);
GAIA – geometrical analysis for interactive aid;
MABAC – multi-attributive border approximation-area comparison;
MAIRCA – multi-attribute ideal-real comparative analysis;
MCDM – multi-criteria decision-making;
MDMA – multi-criteria decision-making analysis;

MGE – multilevel gray evaluation;
PDO – property damage only;
PROMETHEE – preference ranking organization method for enrichment of evaluations;
R-ARAS – rough ARAS;
R-BMW – rough BMW;
R-COPRAS – rough COPRAS;
R-MABAC – rough MABAC;
R-SAW – rough SAW;
R-WASPAS – rough WASPAS;
RSR – road safety risk;
SAW – simple additive weighting;
SCC – Spearman's correlation coefficient;
TOPSIS – technique for order of preference by similarity to ideal solution;
WASPAS – weighted aggregated sum product assessment;
WHO – World Health Organization.

Introduction

The adequacy of transport system has a huge impact on an entire economic system, since today the development of a country is observed directly through the development of transport. In developed countries, the dominant mode of transport is road transport, since it allows the so-called "door-to-door" transport. However, in addition to numerous advantages, road transport is the least safe mode of transport, which is indicated by the number of traffic accidents and victims that occurs around the world every day. According to data of the WHO, approximately 1.35 million people per year are killed in traffic accidents. Between 20 and 50 million people suffer injuries that do not result in fatal outcomes, but many of them have a permanent disability as a consequence. Additionally, the data of the World Health Organization show that injuries caused by traffic accidents are the leading cause of death for children and youth aged 5…29, and that more than half of the killed encompass vulnerable traffic participants such as pedestrians, cyclists and motorcyclists. The data justifies the great commitment and attention of the entire world to improving the safety of traffic.

The motive for the research and analysis carried out in this paper is the high mortality rate of the population in Libya caused by traffic accidents. The reasons for the occurrence of such a large number of traffic accidents are numerous, and road and traffic conditions are such that it is very difficult to predict the actions that drivers, as well as other traffic participants, will carry out on the roads of this country. The wind combined with sand is very common on the roads of Libya, which causes reduced visibility even under day conditions, and hence difficulties in driving. In addition, poor road conditions cause danger, but also domestic and wild animals that cross the roads every day should not be forgotten. There is no public urban transportation, and pavements and other areas intended for pedestrians and other vulnerable traffic participants are in very poor condition. Although the problems in the area of traffic safety are visible and evident in Libya, there is still no adequate methodology or solutions to help and improve road safety. Bearing this in mind, the authors of this paper have paid attention to finding an adequate and applicable solution to the problem of traffic safety in this country. Therefore, the aim of this paper is to create a unique methodology for treating problems in the field of traffic safety. The development of such a methodology is possible through the application of various multi-criteria methods that enable the identification and evaluation of indicators that have a significant impact on reducing the number of traffic accidents, and consequently also on the improvement of traffic safety. In addition, the goal is to point to the problem of traffic safety in Libya with an emphasis on the cities with the largest number of traffic accidents that are a potential danger to traffic participants. By ranking the 10 most deprived cities, using different multi-criteria methods, it has been determined which city is the safest and representative as a model for improving traffic safety in Libya. A similar study was carried out in research by Castro-Nuño & Arévalo-Quijada (2018) where 50 provinces in Spain were ranked by using MDMA, illustrating the number of traffic accidents in the period from 2000 to 2015. Hajeeh (2012) presented the number of violations and car accidents in the period 2000–2009 and by using the AHP method found that in order to solve traffic problems in Kuwait, it is necessary to reduce the number of traffic accidents and congestion. Analysis of traffic accidents (2013–2017) is also illustrated in research by Jakimavičius (2018) where the author used the AHP method for ranking road sections and the result presents 3 most dangerous sections, which are identified as black spots. Anđelković *et al.* (2018) have presented a new statistical model for the identification of dangerous locations (subsections) on roads, also known as hotspots. A practical application of the new model is performed using a sample of 8442 traffic accidents, of which 6079 were PDO accidents, 2041 resulted in injuries and 322 resulted in fatalities.

This paper consists of several sections and subsections. The introduction emphasizes the importance of traffic safety, as well as the motive and aim of the research carried out. The following section provides a review of studies from the aspect of transport and traffic safety, in which different multi-criteria methods have been applied to solve the problem. The section on the methodology presents an integrated MCDM model for ranking the 10 most deprived cities in Libya. The subsection describes the state of traffic safety with an accent on the number, type and cost of traffic accidents from 1995 to 2018, as well as the characteristics of the 10 cities that are the subject of the research. The results represent the determination of the values of the criteria using the FUCOM method and the rough Dombi aggregator and ranking the alternatives using the R-SAW method. In the section dealing with a sensitivity analysis and discussion, the proposed model is compared with other approaches developed recently. In the last section, a conclusion and future research directions are provided.

1. Literature review

Multi-criteria methods are increasingly applied in practice when making important decisions. The significance of these methods is also reflected in their application in solving problems in traffic and transport. They have found their place in solving problems related to the specific field of traffic, today very popular, traffic safety. Below are presented 2 subsections in which is given a review of literature in traffic and transport, as well as in the field of traffic safety.

1.1. Review of MCDM methods in field of traffic safety

Pilko *et al.* (2017) developed a model that used a multi-criterion AHP method for evaluating and ranking traffic parameters and geometric elements of single-lane roundabouts in order to improve the safety and efficiency of traffic. They have done research on 3 roundabouts in Zagreb, Croatia and found out that the most important sub-criteria are entry capacity, designed speed, construction costs, exhaust gas emission and inscribed circle diameter, while queue length, user survey, traffic equipment and signaling costs, traffic noise and exit radius are less important. Fancello *et al.* (2014) used ELECTRE III algorithms to rank dangerous road sections and thus identify those that required emergency intervention. They ranked ten road sections in Sardinia, Italy and those sections that are in the top places are the most critical ones. Then, a method known as Concordance Analysis was also applied to identify road sections requiring interventions to provide better traffic safety conditions (Fancello *et al.* 2015). This research is also done at the motorway in Sardinia and there are used the same 3 different target areas like in the previous research from the same authors (mobility, geometry and safety). Finally, Fancello *et al.* (2019) applied VIKOR and TOPSIS methods and compared them with the results obtained using Concordance Analysis. Application of TOPSIS method to this critical road sections gave the best results. In research by Xi *et al.* (2016), the AHP method was used to rank the causes of traffic accidents according to their significance, in order to select the most influential ones. Results showed that driver factor is the main cause of traffic accidents and following are road, environmental factor and state of the vehicle. Kanuganti *et al.* (2017) identified the most dangerous roads and by applying 3 different methods: SAW, AHP and fuzzy AHP, they determined and quantified important safety parameters and compared the results. They used 4 roads like alternatives and 12 criteria like sight distance, sharp curves, shoulder width, etc. Mirmohammadi *et al.* (2013) used multi-criteria methods (AHP, SAW and TOPSIS) to identify factors that could affect the reduction in the number and severity of traffic accidents in Iran. They have found that the AHP method is the best for identifying indicators that can affect the improvement of traffic safety. Khorasani *et al.* (2013) have evaluated the traffic safety indicators in 21 European countries using multi-criteria methods in order to determine which country has the best performance for reducing traffic accidents. They used 3 methods such as SAW, AHP and fuzzy TOPSIS for ranking. In research by Janackovic *et al.* (2013), the key performance indicators in road construction companies have been identified and ranked on the basis of research results carried out by experts who assessed the safety risk in those companies. Researchers proved that organisational factors are the most important and they are followed by environmental, human and technical factors. According to Temrungsie *et al.* (2015), the most important factors affecting the safety of traffic are the measures of police coercion and knowledge of traffic rules, as determined by the analysis using the AHP method. Sarrazin & De Smet (2015) used the PROMETHEE–GAIA method to enable designers to evaluate safety indicators and evaluate the economic and environmental impacts of their road projects. They created a preventive evaluation model and determine 13 criteria, which are related to the problem. Chen *et al.* (2015) applied an improved multi-criteria method in order to carry out the process of evaluating the road safety risk. This improved entropy TOPSIS–RSR methodology is based on road safety risk index. In research by Podvezko & Sivilevičius (2013), 9 types of interactions between the elements of transport system was presented, and the influence of these interactions on traffic accidents was determined using the AHP method. Sordyl (2015) also used the AHP method to assess and evaluate factors that affect traffic safety and results showed that the most important factors are forcing the-right-of-way, inappropriate speed, wrong overtaking, driving under the influence of alcohol or narcotics, wrong lane changing and not keeping a safe following distance. Şerbu *et al.* (2014) suggested the ranking of intersection types using the TOPSIS method, in order to reduce the number of traffic accidents with pedestrians. A similar problem related to locating hazardous places in Bosnia and Herzegovina using the MCDM model has been addressed in research by Nenadić (2019), where it has been determined that adequate management of this area implies knowledge of priority hazardous areas where traffic infrastructure needs to be improved. There are some studies on traffic accidents in Libya, where the studies attempt to shed light on this problem, or try to analyse the factors that led to these incidents. Abdulfatah Elturki & Albrka Ali (2018) classified the most important factors affecting road traffic accidents in Tripoli. According to Yahia & Ismail (2011), the dense population in cities led to congestion and increase number of accidents inside the cities. They analysed the traffic accidents in 6 cities. Yahia *et al.* (2014) studied age and gender related differences in driver's attitudes towards violations of traffic laws in Tripoli city. Improving general public transportation may have positive effect on reducing number of accidents (Yahia, Ismail 2011).

1.2. Review of MCDM methods in traffic and transport

Pérez *et al.* (2015) have presented the importance of using multi-criteria methods throughout an analysis that includes more than 30 years of application of these methods in urban passenger transport systems. Macharis & Bernardini (2015) have presented a review of 276 papers using multi-criteria methods for evaluating transport projects and found that the AHP method is the most common. Ivanović *et al.* (2013) used the ANP method for selecting projects in road transport. This paper is focused on street reconstruction into pedestrian area where 3 alternatives were defined and the best results were accomplished with the 3rd alternative, which implies complete street reconstruction into a pedestrian zone. For the selection of the location of roundabouts on the city network, Stević *et al.* (2018) used 2 multi-criteria methods: R-BWM and R-WASPAS. To solve the problem of parking in the area of Vilnius, Palevičius *et al.* (2013) applied several methods: SAW, TOPSIS, COPRAS and AHP method. They did research in 8 main residential districts of this city and showed which one has the best and which one has the worst parking conditions. In the same city, Jakimavičius & Burinskienė (2013) assessed the introduction of a new tram line using TOPSIS and SAW methods, and both methods showed the same result, e.g., 2nd alternative, which has 2 tram lines. Pamučar *et al.* (2018a) conducted a survey of ten level crossings across the railroad using the multi-criteria FUCOM–MAIRCA model and they proved that alternative one is 1st ranked by consideration of 7 criteria. Oltean-Dumbrava *et al.* (2016) applied 3 methods, SAW, PROMETHEE and ELECTRE III, to ensure the sustainability of 2 noise reduction projects in transport. In research by Ruiz-Padillo *et al.* (2016), a selection of technical solutions for the problem that causes traffic noise using the ELECTRE and TOPSIS methods has been performed. F-BEM was presented in research by Rossi *et al.* (2013) in order to evaluate and select policies related to reducing traffic pollution and it was compared with AHP method. In research by Radović *et al.* (2018), a model for evaluating key performance indicators in transport companies in 3 countries using the R-ARAS approach was developed. Chen *et al.* (2014) applied MGE and TOPSIS method to evaluate transport performance and service levels in large transport terminals. Both methods gave similar results, i.e., gave advantage transfer alternatives from bus and railway to subway and between bus and railway. Solecka (2014) ranked 8 variants of integrated public transport in Krakow (Poland) using the ELECTRE III method. For this purpose, she used ten criteria and final results suggest the tram variant. Nosal & Solecka (2014) has also assessed which variant of integrated public transport in Krakow is the best, but this time with the AHP method. They used same ten criteria from previous paper and recommended results for AHP method are tram-sub variant and dual-system tram.

2. Material and methods

This paper presents an integrated MCDM model for ranking cities in Libya from the aspect of traffic safety. The proposed model implies the application of the FUCOM method for determining the significance of 8 criteria considered, while the SAW method in rough form is applied to ranking of cities.

2.1. Proposed research methodology

Figure 1 shows research methodology consisting of 3 phases and a total of 9 steps, which are explained in more detail.

The 1st phase consists of 5 steps representing data collection and the formation of a MCDM model. The 1st step is the need for the research that has arisen as a consequence of the situation in the world in the field of traffic safety, particularly the situation in Libya, which is the country with the largest number of traffic accidents and the most severe consequences in the world. The 2nd step involves the definition of specific problems and aims already explained in the introductory part of the paper. Subsequently, in the 3rd step, there is the collection of data in order to determine the number of traffic accidents in the period 1995–2018, their classification, the determination of the costs they cause and the state of the infrastructure. In the 4th step of the 1st phase, a MCDM model is formed, and it includes the definition of a set of alternatives, a set of criteria and an expert team for determining the significance of the criteria and for evaluating the alternatives, which is performed in 5th step. The 2nd phase implies the implementation of the integrated MCDM model in order to obtain the desired results. The 1st step of this phase is the analysis and sorting of data, i.e., their processing, while the 2nd step is the preparation of data for the calculation. The 3rd step includes the formation of the integrated MCDM model in which the values of the criteria by each decision-maker are determined. After that, the transformation into rough numbers is performed and the rough Dombi aggregator is applied to obtain the final values of the criteria. In order to complete the calculation, it is necessary to transform individual matrices into rough ones, after which the rough Dombi aggregator is again applied for its averaging. Finally, the steps of the R-SAW method are applied and the alternatives are ranked. The 3rd phase is a sensitivity analysis that implies the change of the parameter ρ in the range of 1…10, the application of other rough approaches and the calculation of the SCC in order to determine the correlation of the ranks of alternatives.

The benefits of the applied methodology are reflected in the adequate treatment of the uncertainties that exist in such decision-making issues and the reduction of subjectivity using the steps of the FUCOM method (Pamučar *et al.* 2018b). The FUCOM method is a new method for determining the significance of the criteria applied in several studies by now – Zavadskas *et al.* (2018); Nunić (2018);

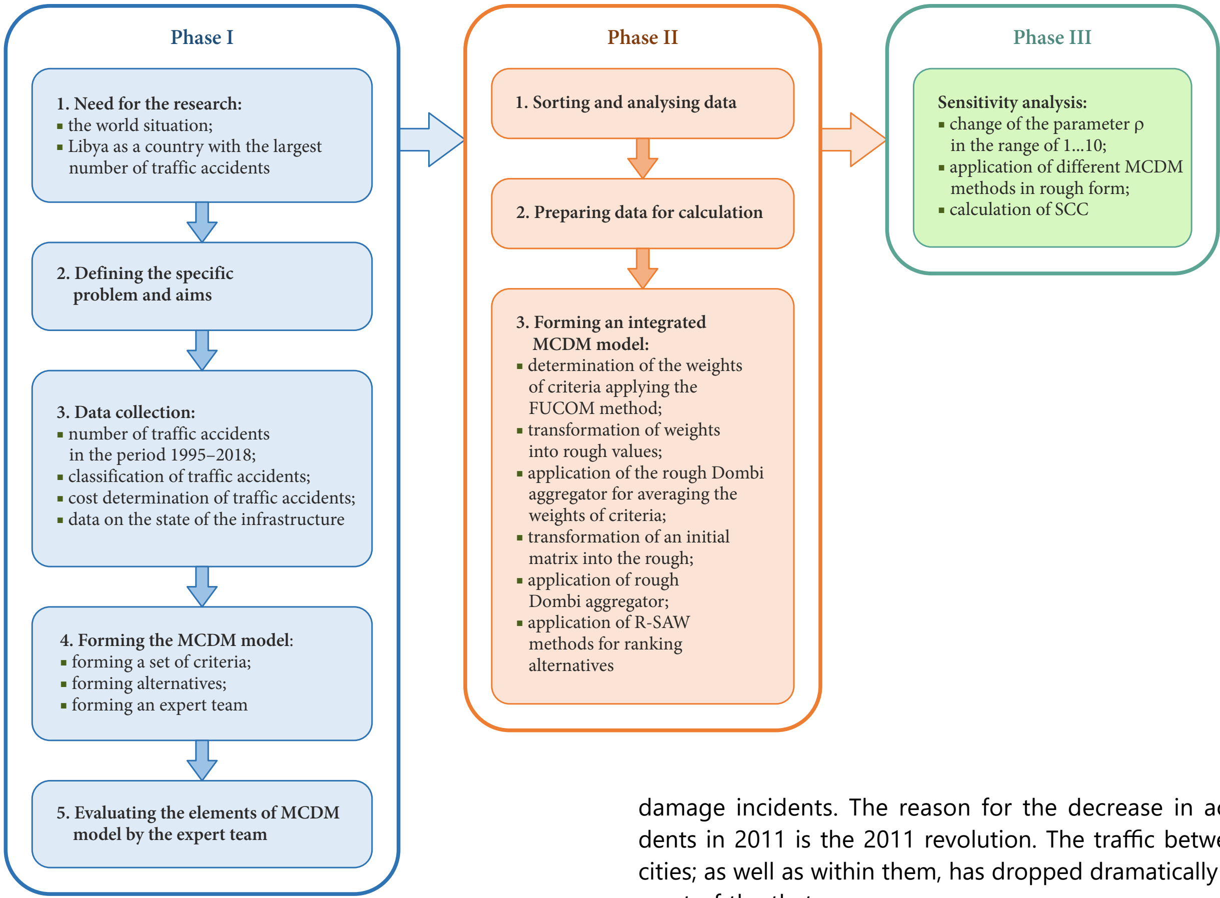

Figure 1. Proposed research methodology

Prentkovskis *et al.* (2018); Erceg & Mularifović (2019); Fazlollahtabar *et al.* (2019); Božanić *et al.* (2019), Badi *et al.* (2022); Stević *et al.* (2023) etc. The rough Dombi aggregator is used for averaging the values of the criteria and for averaging the initial matrix, which contributes to the accuracy of the results obtained. Using the SAW method in rough form, cities in Libya were ranked and certain most dangerous and safest places were determined.

Further, a need for the research throughout a description of the state of safety in Libya and the way of forming a multi-criteria model have been presented.

2.2. Description of traffic safety in Libya

With the growth of transportation demand, the impact on crashes, death, and injuries from road accidents have reached high levels worldwide. Libya is plagued by a weak transport system, which results in enormous problems of traffic congestion (Radović *et al.* 2018). The total number of registered vehicles for 2013 in Libya is 3553497 (WHO 2018). It is considered on the top list of the highest traffic accidents in the world, with a mortality rate of 26.1 persons per 100000. Figure 2 shows the number of traffic accidents during the years 1995 to 2018, whether those resulting in deaths, serious or minor injuries or property damage incidents. The reason for the decrease in accidents in 2011 is the 2011 revolution. The traffic between cities; as well as within them, has dropped dramatically for most of the that year.

Figure 3 shows the number of deaths due to traffic accidents and the costs of damage resulting from the accidents in the same period.

It is clear from these indicators that they are high compared to the rest of the world. The data on traffic accidents in different Libyan cities were analysed between 2014 and 2018 according to the number of accidents causing deaths. Based on these data, the 10 cities with the largest number of accidents during this period were identified and evaluated. Table 1 shows these cities, as well as the population of each city. It can be noted that all these cities are coastal cities, where about 97% of the population lives in coastal cities. The population of the cities of Tripoli, Benghazi, Misurata and Azzawia accounts for more than 45% of Libya's population.

Figure 4 shows the number of accidents with deaths for the last 5 years period 2014–2018. The number of deaths in the top ten cities equals more than 50% of the total deaths in the whole country.

This section also deals with the state of roads in Libya in general in terms of engineering design and evaluation of traffic, in addition to the general condition of paving. The status of road network in Libya is currently considered deteriorated for several reasons; the most important is the suspension of work in all infrastructure projects, the suspension of maintenance works and for the other destructions caused by the war. There is urgent need for road maintenance in all cities.

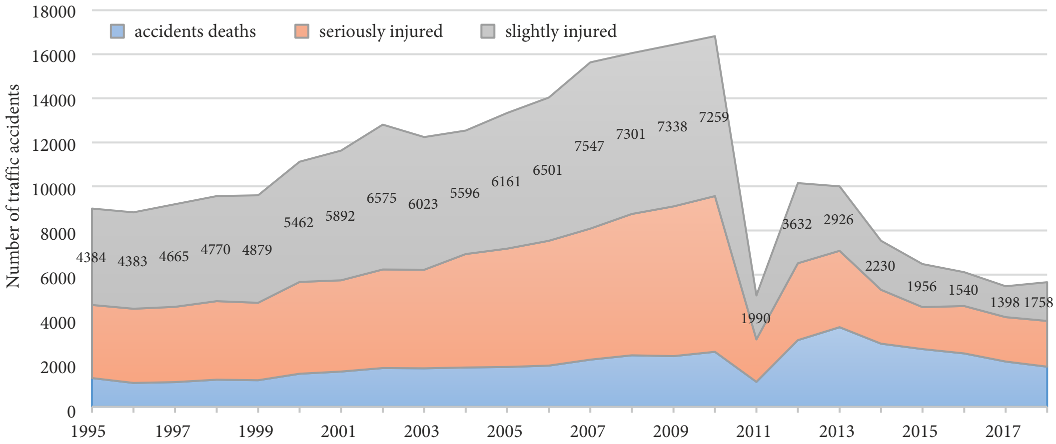

Figure 2. Number of traffic accidents in period 1995–2018

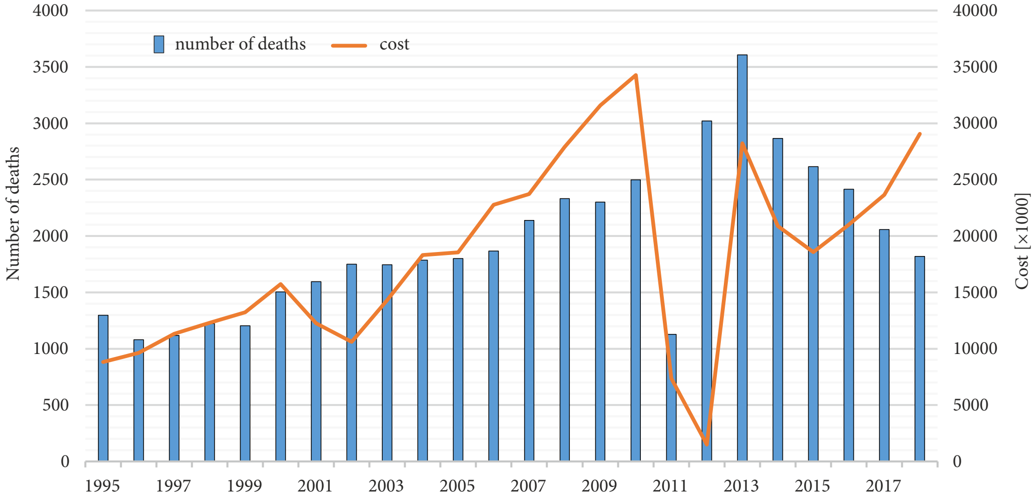

Figure 3. Number of deaths due to traffic accidents and the costs of damage resulting from the accidents in period 1995–2018

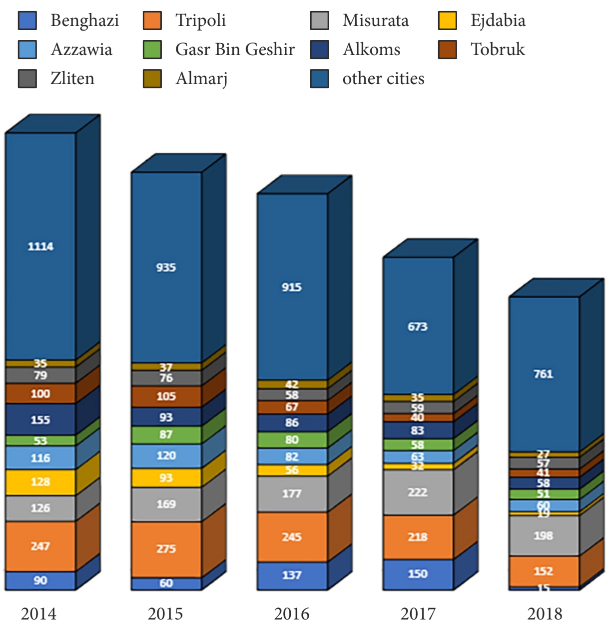

Figure 4. Number of accidents with deaths for the last 5 years period 2014–2018

Table 1. Population rate and characteristics of Libyan cities

City	Population rate	Characteristics
Benghazi	562067	The 2nd biggest city in terms of population. It is considered an important economic center for the Eastern Region. It has a commercial sea port and an airport. It has the headquarters of many Libyan companies and institutions, and it has the oldest Libyan university, which a lot of Libyan youths consider as a destination for study.
Tripoli	940653	The Libyan capital and Libya's largest city. It has the main airport of the country, and most of the headquarters of companies and government institutions, in addition to foreign embassies. Also, it has a commercial seaport, and there are also many companies and factories.
Misurata	502613	It is the home of many businessmen of the country. It has a commercial seaport feeding the central area, plus an airport. Also, it has the largest factory in the country, the Libyan Iron and Steel Complex, as well as many private factories. The presence of the port and the Iron and Steel Complex as well as Al-Brega company fuel reservoir clearly affects the movement of heavy transport vehicles.
Ejdabia	130335	It has strategic location, where it is located at a crossroads, the 1st is the coastal road, the 2nd is the shortcut leading to Tobruk, and the 3rd is Kufra road.
Azzawia	300894	It is 50 km west of the capital. There are many industrial and service institutions in addition to one of the largest universities in Libya. There is also an oil refinery. Most of the cars heading west pass through it in the direction towards the Tunisian border.
Gasr Bin Geshir	59021	Located south of the capital Tripoli, and contain the main airport of the country, which makes traffic heavy.
Alkoms	88317	It has a large commercial port, in addition to cement factory, which increases the movement of trucks. Also, it connects the traffic between the central and western region.
Tobruk	164440	It has a commercial port, 2 oil ports and an airport. It is also the end of the desert road that starts from Ejdabia. It is the eastern gateway to Libya, which is 150 km from the Egyptian border.
Zliten	180000	It has several factories, but most important of which are 2 cement factories, as well as a large feed factory. It is an important commercial center in the region.
Almarj	190001	It has several factories. It is also an important meeting point for land transport between the eastern regions.

Road geometry plays an important role in highway design and safety. Roads in Libya are generally designed and conform to specifications (Roads in Libya are generally designed in conjunction with standards and guidelines). The general condition in terms of the design of lanes and passages as well as the presence of traffic signs in Tripoli, Misurata, Benghazi and Azzawia cities is better compared to other cities. However, most areas lack these signs. However, they lack an important aspect of planning that affects safety, namely the deficiency of traffic signs and traffic markings. Most roads lack warning signs for speed reduction or that which alert drivers to curves. If any, they are outdated, worn out and unclear. In addition, most roads lack ground markings, or the paint is old and unclear. Areas of crossroads and curves suffer from the absence of reflectors or side barriers. It is also important to note that the actual road width is less than the width of the paved road due to soil or sand movement, ad boards too close to the road shoulder, or the exploitation of the rights of way by the shops to put their goods or even exploited by people as parking lots. Also, the entry to or exit from highways is random and uncontrollable (no ramps).

Pavement condition in Libya varies from one road to another based on deterioration severity. The rate of deterioration ranges from poor condition of seriously damaged roads that need reconstruction to fair condition that need major rehabilitation or maintenance. Roads also suffer from several distress types because of the lack of routine maintenance or of the lack of plans for early treatment, especially the minor problems of small pits and superficial cracks that are exacerbated to become clear defects that prevent the road to function and increase the accidents rates. Moreover, the State has not financed or implemented road paving or infrastructure projects in the recent years. There are other drawbacks in roads that are usually due to design standards such as the use of one type of asphalt throughout the country without taking into account the different climatic conditions between the north and the south. Another example is the use of poor paving materials such as weak or porous aggregates, as well as the problems related to the inability to control quality and monitor the implementation of the work.

Traffic volumes in most cities except Tripoli are not considered very high. The heavy traffic observed in most cities is not real, so to speak. It has nothing to do with traffic volumes. It is mainly due to organizational reasons, which can be summarized as follows:

- congestion in front of buildings whose design does not consider the impact on traffic in terms of providing ways for entry or exit or parking lots. This is clearly observed

in commercial markets, clinics or banks. This problem evidently exists in the centers of the cities;
- traffic congestion at the crossroads due to the use of outdated and traditional controls such as pre-timed signals, due to traffic signals stopping, lack of ground signs or arrows to regulate traffic, lack of improving service level and increasing efficiency of crossroads.

As for traffic composition, the largest proportion of vehicles are private cars followed by pickups with a proportion of trucks with multiple sizes and axes concentrated outside CBD and moving on the highway between the east, west and south of the country. Regarding the diversity of traffic, the shortage of large buses can easily be noted, due the country's lack of public transportation.

2.3. Forming a multi-criteria model

As already mentioned, a total of 10 cities in Libya was ranked from the aspect of traffic safety. The evaluation was carried out on the basis of the following 8 criteria:
- C1 – total number of traffic accidents with killed persons (quantitative data for last 5 years);
- C2 – total number of traffic accidents with seriously injured persons (quantitative data for last 5 years);
- C3 – total number of traffic accidents with slightly injured persons (quantitative data for last 5 years);
- C4 – total number of traffic accidents with PDO (quantitative data for last 5 years);
- C5 – geometric design of road (qualitative data about curves, road width, upgrade, downgrade, etc.);
- C6 – AADT (besides AADT, quantitative data about the structure of traffic flow like passenger cars, buses, trucks are needed);
- C7 – traffic elements (qualitative data about condition of pavement, roadway, road markings – horizontal and vertical signalization);
- C8 – traffic accidents cost (quantitative data for last 5 years).

The 5h and 7th criteria belong to the group of the benefit, while the others are cost criteria. The expert team of 5 decision-makers evaluated the significance of 8 criteria comparing each other, and after that, evaluated the alternatives based on the criteria determined. 3 of the experts are academic, who expertise in road and traffic engineering, logistics and transportation systems, and mechanical engineering (who has been involved in road safety awareness activities) with experience of more than 25 for 2 of them. All of them has a good experience in the field of transportation. The 4th expert Works at Libyan Ministry of Transportation for many years. The 5th expert works at Libyan Ministry of Interior, Department of traffic accidents for several years.

Table 2. Ranking and comparison of the criteria by the expert team

E1	C1	C2	C7	C5	C3	C4	C6	C8
C1	1	2	2.5	3	4	4	4.5	5
E2	C1	C2	C3	C5	C7	C8	C4	C6
C1	1	3	4	5	5	6	6	7
E3	C1	C2	C3	C4	C6	C5	C7	C8
C1	1	4	5	6.5	7	7.5	8	9
E4	C1	C2	C3	C8	C4	C7	C5	C6
C1	1	3	5	6	6	7	8	9
E5	C1	C2	C3	C4	C7	C5	C6	C8
C1	1	2	4	5	5	6	7	8

Table 2 presents the comparison of all criteria by each decision-maker, while Table 3 shows the evaluation of cities according to the criteria using the linguistic scale by all experts developed in research by Stević *et al.* (2017).

3. Results

3.1. Determining the values of the criteria applying the FUCOM method and the rough Dombi aggregator

After the ranking and comparison of the criteria shown in Table 2, it is necessary to calculate the comparative importance values of criteria for each expert. The example of the calculation for the 1st decision-maker is shown below.

E_1:

$\varphi_{C_1/C_2} = 2/1 = 2;$

$\varphi_{C_2/C_7} = 2.5/2 = 1.25;$

Table 3. Individual decision-making matrices according to experts

	C1					C2					…	C7					C8				
	E1	E2	E3	E4	E5	E1	E2	E3	E4	E5		E1	E2	E3	E4	E5	E1	E2	E3	E4	E5
Benghazi	5	7	4	6	9	7	9	8	9	9		7	7	4	7	9	7	7	8	9	6
Tripoli	7	9	8	8	9	5	8	4	6	7		7	8	4	9	9	7	8	8	9	5
Misurata	7	8	5	7	8	5	7	3	5	6		7	7	5	8	8	7	7	6	7	4
Ejdabia	4	5	2	3	5	4	4	2	4	4		5	5	5	6	7	5	5	7	7	3
Azzawia	4	5	3	4	8	3	3	1	2	3		6	7	4	8	8	6	7	2	4	4
Gasr bin Geshir	4	6	3	5	5	4	4	2	4	3		6	6	3	5	6	6	6	5	7	3
Alkoms	4	6	3	5	4	3	3	1	3	3		6	6	3	6	3	6	6	5	4	2
Tobruk	4	5	2	4	4	4	4	2	4	3		6	5	2	5	4	6	5	3	2	2
Zliten	4	5	2	4	3	3	3	1	2	2		6	5	2	4	4	6	5	3	3	2
Almarj	3	4	1	3	1	3	3	1	2	2		5	5	1	4	2	5	5	4	7	1

$\varphi_{C_7/C_5} = 3/2.5 = 1.20;$
$\varphi_{C_5/C_3} = 4/3 = 1.33;$
$\varphi_{C_3/C_4} = 4/4 = 1;$
$\varphi_{C_4/C_6} = 4.5/4 = 1.12;$
$\varphi_{C_6/C_8} = 5/4.5 = 1.11.$

Final values of weight coefficient should satisfy 2 conditions:

- final values of weight coefficient should satisfy the condition where:

  E_1:
  $w_1/w_2 = 2;$
  $w_2/w_7 = 1.25;$
  $w_7/w_5 = 1.20;$
  $w_5/w_3 = 1.33;$
  $w_3/w_4 = 1;$
  $w_4/w_6 = 1.12;$
  $w_6/w_8 = 1.11;$

- in addition to the defined relations, final values of weight coefficients should satisfy also the condition of mathematical transitivity, respectively:

  E_1:
  $w_1/w_7 = 2 \cdot 1.25 = 2.50;$
  $w_2/w_5 = 1.25 \cdot 1.2 = 1.50;$
  $w_7/w_3 = 1.2 \cdot 1.33 = 1.60;$
  $w_5/w_4 = 1.33 \cdot 1 = 1.33;$
  $w_3/w_6 = 1 \cdot 1.12 = 1.12;$
  $w_4/w_8 = 1.12 \cdot 1.11 = 1.24.$

After that, the models for determining weight coefficients for each decision-maker can be defined:

DM_1
$\min \chi$
subject to:

$$\left|\frac{w_1}{w_2} - 2\right| = \chi;$$
$$\left|\frac{w_2}{w_7} - 1.25\right| = \chi;$$
$$\left|\frac{w_7}{w_5} - 1.20\right| = \chi;$$
$$\left|\frac{w_5}{w_3} - 1.33\right| = \chi;$$
$$\left|\frac{w_3}{w_4} - 1\right| = \chi;$$
$$\left|\frac{w_4}{w_6} - 1.12\right| = \chi;$$
$$\left|\frac{w_6}{w_8} - 1.11\right| = \chi;$$
$$\left|\frac{w_1}{w_7} - 2.5\right| = \chi;$$
$$\left|\frac{w_2}{w_5} - 1.5\right| = \chi;$$
$$\left|\frac{w_7}{w_3} - 1.6\right| = \chi;$$
$$\left|\frac{w_5}{w_4} - 1.33\right| = \chi;$$
$$\left|\frac{w_3}{w_6} - 1.12\right| = \chi;$$
$$\left|\frac{w_4}{w_8} - 1.24\right| = \chi;$$
$$\sum_{j=1}^{8} w_j = 1,\ w_j \ge 0,\ \forall j.$$

By solving the model for the 1st decision-maker, the following weight values of the criteria are obtained: C1 = 0.317, C2 = 0.158, C3 = 0.079, C4 = 0.079, C5 = 0.106, C6 = 0.070, C7 = 0.127, C8 = 0.063. In the same way, the values are obtained for each criterion by each decision-maker individually, as shown in Table 4.

The final values shown in the last column of Table 4 are obtained applying rough operations and the rough Dombi aggregator. 1st, the transformation of individual matrices into a group rough matrix is made. As an example, the calculation of values for the 1st criterion is provided. Crisp values for the 1st criterion by all decision-makers are $\tilde{c}_1 = \{0.317, 0.407, 0.473, 0.445, 0.387\}$. By applying basic operations with rough numbers, the following values are obtained:

$RN(c_1^1) = [0.317, 0.410];$
$RN(c_1^2) = [0.370, 0.440];$

Table 4. The final values of the criteria obtained applying the FUCOM method and the rough Dombi aggregator

	C1	C2	C3	C4	C5	C6	C7	C8
DM1	0.317	0.158	0.079	0.079	0.106	0.070	0.127	0.063
DM2	0.407	0.136	0.102	0.068	0.081	0.058	0.081	0.068
DM3	0.473	0.118	0.095	0.073	0.063	0.068	0.059	0.053
DM4	0.445	0.148	0.089	0.074	0.056	0.049	0.064	0.074
DM5	0.387	0.193	0.097	0.077	0.064	0.055	0.077	0.048
Final rough values	[0.364, 0.441]	[0.133, 0.169]	[0.085, 0.098]	[0.070, 0.078]	[0.063, 0.084]	[0.053, 0.066]	[0.067, 0.121]	[0.053, 0.066]

$$RN\left(c_1^3\right)=\left[0.410,\, 0.473\right];$$
$$RN\left(c_1^4\right)=\left[0.39,\, 0.46\right];$$
$$RN\left(c_1^5\right)=\left[0.35,\, 0.43\right].$$

After the transformation has been made, 5 rough matrices are obtained and the operations of the rough Dombi aggregator are applied to them. As mentioned in the previous part of the paper, the research involved 5 experts who were assigned the same weight values of 0.200. Based on the displayed values, the Equation (8) from research by Stević *et al.* (2018) and assuming that ρ = 1 is in position C1, the aggregation of values has been performed:

$$RNDWGA\left(c_1\right)=\begin{cases}a_1;\\ a_2,\end{cases}$$

$$a_1=\underline{Lim}\left(c_1\right)=\frac{\sum_{j=1}^{5}\underline{Lim}\left(\varphi_j\right)}{1+\left(\sum_{j=1}^{5}w_j\cdot\left(\frac{1-f\cdot\left(\underline{Lim}\left(\varphi_j\right)\right)}{f\cdot\left(\underline{Lim}\left(\varphi_j\right)\right)}\right)^{\rho}\right)^{1/\rho}}=$$

$$\frac{1.837}{1+\left(0.200\cdot\left(\frac{1-0.173}{0.173}\right)+0.200\cdot\left(\frac{1-0.201}{0.201}\right)+\ldots+0.200\cdot\left(\frac{1-0.191}{0.191}\right)\right)}=0.364;$$

$$a_2=\overline{Lim}\left(c_1\right)=\frac{\sum_{j=1}^{5}\overline{\grave{u}}\left(\varphi_j\right)}{1+\left(\sum_{j=1}^{5}w_j\cdot\left(\frac{1-f\cdot\left(\overline{Lim}\left(\varphi_j\right)\right)}{f\cdot\left(\overline{Lim}\left(\varphi_j\right)\right)}\right)^{\rho}\right)^{1/\rho}}=$$

$$\frac{2.213}{1+\left(0.200\cdot\left(\frac{1-0.185}{0.185}\right)+0.200\cdot\left(\frac{1-0.199}{0.199}\right)+\ldots+0.200\cdot\left(\frac{1-0.194}{0.194}\right)\right)}=0.441.$$

Based on the final values shown in Table 4, it can be concluded that the 1st criterion related to the number of traffic accidents with killed persons is the most important on the basis of the ranking by all 5 experts. Then there is the 2nd criterion that also refers to the number of traffic accidents, but with seriously injured persons. The 3rd most important criterion is the traffic elements, and the 4th place is occupied by the criterion with approximate values as well as its predecessor, referring to traffic accidents with slightly injured persons. It is followed by the 4th criterion, which implies traffic accidents with property damage, followed by a criterion that relates to the geometric conditions of road. The 6th and 8th criteria referring to AADT and the cost of traffic accidents are in the last position with identical final values.

3.2. Ranking the alternatives by applying the R-SAW method

In order to apply the proposed methodology, it is necessary to transform individual matrices from Table 3 into a group rough matrix, as it has been the case with the calculation of criterion weights. Subsequently, the rough Dombi aggregator is applied and the final rough values of the alternatives for the initial matrix shown in Table 5 are obtained.

By applying the R-SAW methodology, the initial rough matrix, shown in Table 5, is normalized taking into consideration the minimum and maximum values of the criteria, depending on where they belong. After that, the normalized matrix is weighted by multiplying with the values of the criteria obtained using the FUCOM method and the rough Dombi aggregator. Finally, the values are summarized by the alternatives and the ranks obtained are shown in Table 6.

Table 6. Results of applied MCDM model

	Rough value	Crisp value	Rank
A1	[0.26, 0.70]	[0.48]	9
A2	[0.24, 0.67]	[0.45]	10
A3	[0.29, 0.80]	[0.55]	8
A4	[0.33, 0.97]	[0.65]	7
A5	[0.37, 1.09]	[0.73]	4
A6	[0.35, 1.03]	[0.69]	6
A7	[0.35, 1.08]	[0.71]	5
A8	[0.39, 1.14]	[0.77]	3
A9	[0.42, 1.30]	[0.86]	2
A10	[0.42, 1.70]	[1.06]	1

Table 5. Initial aggregated rough matrix

	C1		C2			C7		C8	
A1	[4.92, 7.33]	[7.89, 8.82]	[4.92, 7.33]	[7.89, 8.82]		[5.70, 7.60]	[5.70, 7.60]	[6.95, 8.52]	[6.95, 8.52]
A2	[7.72, 8.63]	[4.90, 6.93]	[7.72, 8.63]	[4.9, 6.93]		[5.81, 8.42]	[5.81, 8.42]	[6.41, 8.47]	[6.41, 8.47]
A3	[6.24, 7.58]	[4.17, 5.97]	[6.24, 7.58]	[4.17, 5.97]		[6.24, 7.58]	[6.24, 7.58]	[4.90, 6.93]	[4.90, 6.93]
A4	[2.84, 4.49]	[3.10, 3.91]	[2.84, 4.49]	[3.1, 3.91]		[5.16, 6.01]	[5.16, 6.01]	[4.49, 7.02]	[4.49, 7.02]
A5	[3.74, 5.76]	[1.71, 2.81]	[3.74, 5.76]	[1.71, 2.81]	.	[5.38, 7.46]	[5.38, 7.46]	[2.67, 3.61]	[2.67, 3.61]
A6	[3.83, 5.21]	[2.81, 3.81]	[3.83, 5.21]	[2.81, 3.81]	.	[4.31, 5.77]	[4.31, 5.77]	[4.26, 6.61]	[4.26, 6.61]
A7	[3.69, 5.02]	[1.97, 2.91]	[3.69, 5.02]	[1.97, 2.91]	.	[3.87, 5.45]	[3.87, 5.45]	[3.11, 4.96]	[3.11, 4.96]
A8	[3.09, 4.28]	[2.81, 3.81]	[3.09, 4.28]	[2.81, 3.81]		[3.20, 5.16]	[3.20, 5.16]	[2.32, 2.83]	[2.32, 2.83]
A9	[2.79, 4.20]	[1.61, 2.60]	[2.79, 4.2]	[1.61, 2.60]		[3.11, 4.96]	[3.11, 4.96]	[2.67, 3.61]	[2.67, 3.61]
A10	[1.46, 2.97]	[1.61, 2.60]	[1.46, 2.97]	[1.61, 2.60]		[1.86, 4.32]	[1.86, 4.32]	[2.31, 5.80]	[2.31, 5.80]
max	[7.72, 8.63]	[7.89, 8.82]	[7.72, 8.63]	[7.89, 8.82]		[6.24, 8.42]	[6.95, 8.52]	[6.24, 8.42]	[6.95, 8.52]
min	[1.46, 2.97]	[1.61, 2.60]	[1.46, 2.97]	[1.61, 2.60]		[1.86, 4.32]	[2.31, 2.83]	[1.86, 4.32]	[2.31, 2.83]

Based on the results of the applied MCDM model, it can be concluded that 10th alternative, i.e., the city of Almarj is the safest, and that it is a representative model for improving traffic safety in Libya. Then the ninth alternative, i.e., city of Zliten, follows. In the 3rd place is the city of Tobruk, and in the 4th place is Azzawia. Then they are followed by the 7th and 6th alternatives, namely the cities of Alkoms and Gasr bin Geshir. Based on traffic safety, the 4th alternative, i.e., the city of Ejdabia, takes the 7th place, while the 8th place is occupied by the t3rd alternative, the city of Misurata. In the penultimate place, there is the 1st alternative, i.e., the city of Benghazi, while Tripoli is the least safe city, which is also the capital of Libya.

The created MCDM model can be also applied for the determination of the level of traffic safety in other cities in other countries in which traffic accidents are one of the leading problems. The experts, by evaluating cities through a set of a number of criteria, clearly indicate a problem, which they need to deal with 1st and point out what should be the most attention paid in order to solve it (whether it is a human factor or a factor of the road and the environment). This integrated model is formed in that way that it doesn't leave so much space for subjectivity during the making of decisions. Also, by pointing to the most dangerous places, i.e., cities, the attention of the public and the authorities is drawn to the necessity of undertaking activities to improve traffic safety.

This efficient method could be applied in other countries, especially those countries with high traffic accidents, to provide the decision-makers in those countries with robust model for improving traffic safety. Also, it can be generalized for other applications of multi-criteria decision-making.

4. Sensitivity analysis and discussion

The sensitivity analysis implies the application of different approaches, and the comparison of the results with the applied FUCOM–R-SAW model in the 1st part. After that, the parameter ρ has been changed in the range of 1...10 in the 2nd part of the sensitivity analysis, and in the 3rd part, the SCC has been calculated. Figure 5 shows the comparison of the proposed model with other approaches developed recently: R-ARAS (Radović *et al.* 2018), R-WASPAS (Stojić *et al.* 2018), R-COPRAS (Matić *et al.* 2019) and R-MABAC (Roy *et al.* 2018).

Figure 4 provides the results obtained by different approaches stated above. Almarj is a city that is the safest by applying all methods. Zliten and Tobruk represent the cities that are the safest after the city of Almarj and do not change their positions in all approaches. It can be said that the stability of the results is at a high level, since only the 5th, 6th and 7th alternatives change their positions. The 5th alternative is in the 4th place using R-SAW, R-ARAS and R-WASPAS, while using R-MABAC it is in the 5th position and in the 6th position using R-COPRAS. The 6th alternative is in the 5th place only by using R-COPRAS, while in other calculations it is in the 6th position. The 7th alternative in R-COPRAS and R-MABAC approaches occupies the 4th position, while in other approaches it is in the 5th place.

Table 7 shows the sensitivity analysis with the change of the parameter ρ in the range of 1...10, and the final values of the alternatives and their ranks, depending on the value of the specified parameter.

Changing the parameter ρ does not affect essentially the ranks of alternatives. Basically, if its value is one or 2, the ranks remain unchanged, while changing the values of this parameter in the range of 3...10, the ranks of the 5th and 7th alternatives are changed. In all cases (ρ = 3...10), the 5th and 7th alternatives change their positions, that is, the 7th is in the 4th place, and the 5th alternative occupies the 5th position.

Figure 6 shows the calculation of SCC for all ranks of alternatives applying different approaches. It can be noticed that the ranks obtained by applying R-SAW are in complete correlation (SCC=1.00) with the ranks obtained using the R-ARAS and R-WASPAS approach, while SCC = 0.988

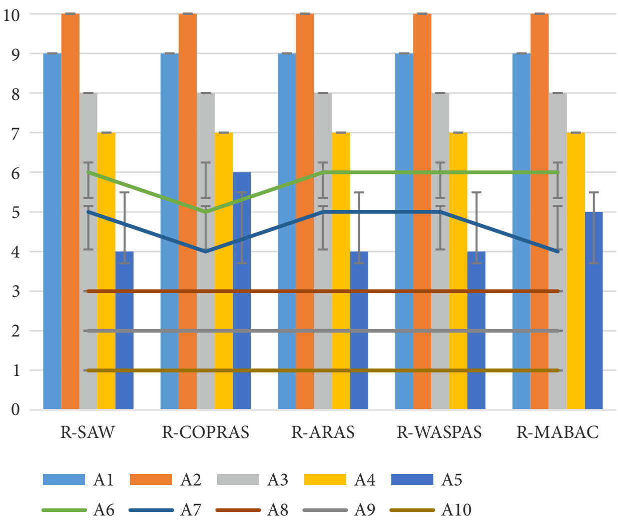

Figure 5. Comparison of the results with other methods

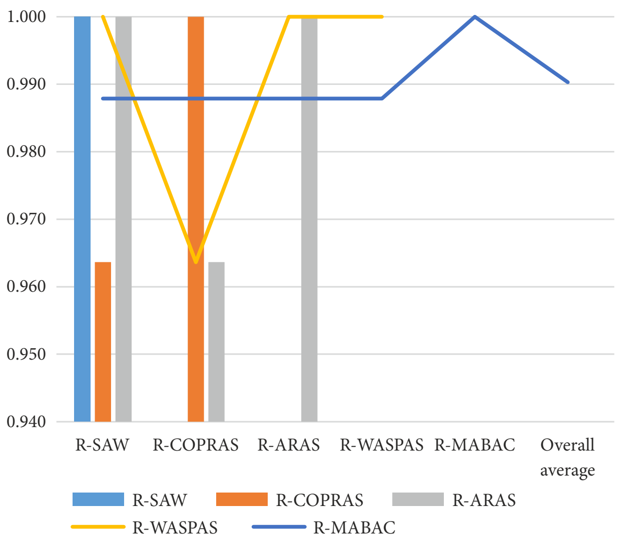

Figure 6. SCC for ranks of alternatives applying different approaches

Table 7. Ranks of alternatives depending on the change of parameter ρ

ρ	Q_i	Rank
ρ = 1	Q1 = 0.473, Q2 = 0.449, Q3 = 0.544, Q4 = 0.648, Q5 = 0.725, Q6 = 0.690, Q7 = 0.712, Q8 = 0.764, Q9 = 0.854, Q10 = 1.057	A10 > A9 > A8 > A5 > A7 > A6 > A4 > A3 > A1 > A2
ρ = 2	Q1 = 0.467, Q2 = 0.441, Q3 = 0.538, Q4 = 0.647, Q5 = 0.724, Q6 = 0.691, Q7 = 0.718, Q8 = 0.760, Q9 = 0.852, Q10 = 1.091	A10 > A9 > A8 > A5 > A7 > A6 > A4 > A3 > A1 > A2
ρ = 3	Q1 = 0.462, Q2 = 0.435, Q3 = 0.534, Q4 = 0.649, Q5 = 0.726, Q6 = 0.695, Q7 = 0.728, Q8 = 0.759, Q9 = 0.853, Q10 = 1.122	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 4	Q1 = 0.459, Q2 = 0.431, Q3 = 0.531, Q4 = 0.652, Q5 = 0.728, Q6 = 0.700, Q7 = 0.738, Q8 = 0.761, Q9 = 0.855, Q10 = 1.145	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 5	Q1 = 0.456, Q2 = 0.428, Q3 = 0.529, Q4 = 0.655, Q5 = 0.731, Q6 = 0.705, Q7 = 0.746, Q8 = 0.764, Q9 = 0.859, Q10 = 1.162	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 6	Q1 = 0.465, Q2 = 0.425, Q3 = 0.528, Q4 = 0.659, Q5 = 0.734, Q6 = 0.709, Q7 = 0.752, Q8 = 0.767, Q9 = 0.862, Q10 = 1.173	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 7	Q1 = 0.454, Q2 = 0.424, Q3 = 0.528, Q4 = 0.662, Q5 = 0.736, Q6 = 0.713, Q7 = 0.757, Q8 = 0.770, Q9 = 0.866, Q10 = 1.182	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 8	Q1 = 0.453, Q2 = 0.423, Q3 = 0.528, Q4 = 0.665, Q5 = 0.738, Q6 = 0.716, Q7 = 0.760, Q8 = 0.772, Q9 = 0.868, Q10 = 1.188	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 9	Q1 = 0.453, Q2 = 0.422, Q3 = 0.528, Q4 = 0.667, Q5 = 0.740, Q6 = 0.718, Q7 = 0.764, Q8 = 0.774, Q9 = 0.871, Q10 = 1.192	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2
ρ = 10	Q1 = 0.453, Q2 = 0.421, Q3 = 0.529, Q4 = 0.670, Q5 = 0.742, Q6 = 0.720, Q7 = 0.766, Q8 = 0.776, Q9 = 0.873, Q10 = 1.195	A10 > A9 > A8 > A7 > A5 > A6 > A4 > A3 > A1 > A2

with R-MABAC and SCC = 0.964 with the R-COPRAS approach. Taking into account the above, it is obvious that R-ARAS and R-WASPAS approaches have total mutual correlation, and with R-MABAC the correlation coefficient is 0.988. The same correlation coefficient with R-MABAC is as with R-COPRAS, while with the other 2 approaches (R-ARAS and R-WASPAS) there is somewhat less correlation SCC = 0.964. When observing the overall correlation coefficient, it is 0.990, which represents almost a complete correlation of ranks.

The increasing number of deaths and injuries caused by road accidents is a serious alert to the decision-makers to tackle this problem more seriously. The number of deaths as a result of traffic accidents may reach to 1.9 million by 2020. Some countries have been successful in reducing road traffic deaths over the recent years, but progress differs widely between the different regions and countries around the world. The number of road traffic deaths in all low-income countries has not been reduced since 2013. This enforces the decision-makers in those countries to look for efficient methods and programs aimed at improving road traffic safety. The study offers guidance for decision-makers to reach their decision in a more organized and strategic way.

The suggested model can play an important role in ranking of cities according to traffic safety, particularly when it is in a situation, where complex real-world problems. By applying this model an adequate results by considering a number of criteria can be obtained, which was rare in the previous studies in this field. The suggested MCDM model involves the integration of FUCOM, rough Dombi and R-SAW methods. One of the most important advantages of the suggested model is that it reduces the uncertainties and subjectivity that exist in decision-making processes. The findings can support plans by the Libyan authorities to decrease the traffic accidents.

Conclusions

Traffic safety issues are present worldwide in varying extent. There is a tendency for constant monitoring and making certain decisions and strategies that will increase the safety of all traffic participants. A large number of studies in this area are based on the measurement of traffic safety indicators and decision-making on the basis of the given measurements, which is only one element that is necessary to observe. Throughout previous studies carried out in this field, the issue of forming a universal model has been imposed which will enable the determination of the level of safety of different cities and towns. Therefore, this paper proposes a unique methodology with emphasis on an integrated MCDM model. The model allows obtaining adequate results by considering a number of criteria, which in previous studies in this field was rare. The integrated MCDM model implies the integration of FUCOM, rough Dombi and R-SAW methods. The application of this model reduces the uncertainties and subjectivity that exist in decision-making processes. The above shows the contribution of this research that also has its practical significance, in addition to the already stated scientific importance. The practical significance of the research implies the identification and ranking of cities in Libya from the aspect of traffic safety in order to determine strategies for its improvement. The results obtained by applying this model show that Almarj is the safest, while Tripoli, Benghazi and Misurata are the most dangerous cities in which it is necessary to make proposals and measures to increase safety as quickly as possible. The performed sensitivity analysis confirms the results obtained. It is particularly important to emphasize that the ranks of alternatives do not change significantly, although there is relatively a huge number of alternatives.

It should be kept in mind that traffic safety in ranked cities is significantly influenced by the state of war in Libya. Emergency situations cause frequent changes in the traffic regime. Also, drivers are not very well educated about traffic rules and laws, and because of that traffic police needs to affect on their behaviour and knowledge of the law, especially in cities that are ranked as the most dangerous. War environment also caused a very bad condition of roads, which are full of holes, faded horizontal signalization and damage of vertical signalization, but also dysfunction of a large number of traffic lights. The created MCDM model can be also applied for the determination of the level of traffic safety in other cities in other countries in which traffic accidents are one of the leading problems. As future research directions, the need for improving the traffic infrastructure, which can significantly affect the reduction of traffic accidents, and the application of the methodologies for identifying various problems in this area are imminent. It would be desirable to point out the existing problems in more detail and to identify individual hazardous locations in all the cities analysed in this research.

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