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RESEARCH PAPER

A Combined Index of Proactive and Reactive Data for Rating the Safety of Road Sections

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Abstract

There are two main methods for reducing the number of road accident fatalities and damages: proactive statistics and reactive statistics. The segments under consideration do not necessarily have the same level of safety risk and should be prioritized based on safety and budget expertise. Using six proactive and reactive criteria, this study presents a new index for ranking segments of a suburban road in terms of safety, namely accidents, roadside conditions, vertical signs, road markings, pavement conditions, and access density. In this study, a hierarchical analysis, a hybrid indicator of combinative distance-based assessment/evaluation based on distance from average solution, and simple weighted models were applied in addition to safety audit and accident index. The Sanandaj-Kermanshah road was selected as a case study for implementing the model. The road was chosen because of its high traffic, importance, and accident rate. In determining the safety risk of segments, accident severity index and access density were the most important factors. Due to the consideration of two steps to verify the prioritization, the CODAS model received the highest weight in the composite indicator. In suburban roads, the proposed index could be used to prioritize budget allocations for road safety. The innovation of this study is the use of a hierarchical and hybrid indicator for proactive data (obtained from safety audits) and reactive data (obtained from accidents). Also, in past studies, they have not examined the combination of proactive and reactive data.

Keywords Prioritization index · Safety risk · Suburban roads

1 Introduction

A number of studies have shown that accidents are the result of a complex interaction between four main factors: the vehicle, the human(Nadimi et al 2024), the road, and the environment (Asadamraji et al. 2022). The road and its environment contribute to 34–58% of all traffic accidents (Xu et al. 2018). Thus, providing a high quality of transport facilities is a major concern for transport operators. Road safety has become one of the most important criteria for design due to the proliferation of road accidents (Sheikholeslami et al. 2020 and 2023). Road-related projects that fail to comply with standards, policies, and safety audits can form accident-prone segments (Rossetti et al. 2014), whereas injury prevention priorities identified by studying burden criteria (Hong et al. 2011) are primarily related to road safety audits. Road safety audits play a very important role in increasing safety (Jamroz et al. 2019). It is possible to identify the black spots on a road by using a set of criteria for checking different road conditions. Accordingly, periodic safety audits are on the agenda of relevant organizations (Huyarinen et al., 2017). Despite the fact that identifying hazardous points or segments does not guarantee that no accidents will occur, it is essential to recognize and study hazardous points or segments (Chen et al. 2020).

Safety audits of hotspots and safety audits have been conducted in a number of countries. As well, road safety audits

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and modifications have been raised before road construction, but are performed periodically under road operation conditions (Sun et al. 2006). According to Loo et al. (2005), several higher priority safety projects are selected based on cost, state criteria, and the number of vehicles passing through. McLeaney et al. (2010) conducted a multi-criteria decision-making study on traffic problems and proposed a model for calculating the safety score of road segments. According to Najib et al. (2012), speed, vision distance, and driver's vision were the most important factors in the occurrence of accidents by using the AHP method (Najib et al. 2012, Yu and Liu 2012). Hosseinian et al. (2023), investigated the impact of safety and efficiency of autonomous vehicles (AVs) in a traffic network. This analysis identifies significant gaps in understanding and suggests avenues for future research to increase understanding of the potential of AVs in increasing the efficiency and safety of traffic networks (Hosseinian et al., 2023). Bathrinath et al. (2021) also examined 20 hazardous parameters using Delphi method and analytical Network Process (ANP) to examine the main causes of accidents (Bathrinath et al. 2021). Additionally, Yakar (2021) evaluated accident-prone road access using linear weighted compounds by focusing on geometric design parameters (Yakar 2021). Antic et al. (2020) used different indicators to evaluate both the results of the passages and the data about existing risks at the same time using both old methods and data envelope analysis (Antic et al., 2020). Jafarzadeh Ghoshchi et al. (2023) evaluated road safety and prioritized risks by applying SWARA and MARCOS integrated approach in a spherical fuzzy environment. The results of the risk assessment showed that the main source of risk (human factor) significantly affects accidents compared to alternative sources of risk (Jafarzadeh Ghoshchi et al., 2023). Hermans et al. (2008) developed a composite safety index by examining seven accident factors and five weighting method. Cafiso et al. (2007) and colleagues assessed a rural highway safety approach utilizing design harmony models and safety evaluations, and acquired the actual collision scenario with the Empirical Bayes (EB) technique. Spearman's rank correlation was utilized to ascertain the level of concurrence between the evaluations acquired by the two methodologies. The findings of Spearman's rank correlation examination validate the safety indicator, indicating that the hierarchy of SI scores and EB approximations align at the 99.9% level of importance with a correlation coefficient of 0.87 (Cafiso et al. 2007). Hermans et al. (2009) introduced a composite safety index based on seven accident factors and five weighting methods, and found the DEA (Sadeghi et al. 2013) to be the most reliable. Mirzahosein et al. (2021) investigated the impact of standard versus non-standard lighting conditions in night traffic using the binary classified intersection lighting accident change coefficient and considering the effects of other potential exposures in 40 urban intersections with a regression model. The results indicate a 23.52% reduction in night accidents at urban intersections with standard lighting (Mirzahosein et al. 2021). According to Muslim et al. (2020), the best-the-worst method and triple fuzzy methods were used to optimize the decision problem for road safety. Using a multi-criteria approach, Fancello et al. identified the most dangerous road segments. Furthermore, they considered a set of indicators and used ÉLECTRE, Vicor, and TOPSIS methods. According to the results, TOPSIS was the most effective method (Fancello et al 2019). Through the full consistency method (FUCOM), Nenadic (2019) defined and evaluated seven safety parameters, including accident rate, average annual traffic, and road segments. An ordinary least square regression model, which relates fatality rate with different explanatory variables, was used for predicting annual road crash fatalities (RCF) in Pakistan (Ahmed et al. 2016). For identifying and prioritizing pedestrian safety criteria on intercity roads, Morradi et al. (Moradi et al. 2021) used the Fuzzy Topsis model. Insurance companies in British Columbia (Canada) identify accident-prone areas using safety audits, and a ranking model is used to prioritize accident-prone segments (Kar and Blankenship, 2010). Researchers at the University of Utah prioritized black spots on roads based on accident reduction parameters, showing that quantitative safety audits are more effective (Jones 2013). Based on experts' ideas and safety audit statistics (Raffo et al. 2013), Park and Young (2014) and Raffo et al. (2013) presented prioritization models and safety approaches. Using AHP, Agarwal et al. (2013) ranked accident black spots for each road segment and calculated pair-wise relative accidents (Agarwal et al. 2013). Also, this method has been used to evaluate the factors obtained from safety audits, and work zones, verticals, and road markings were found to be the most effective factors in reducing the risk of accidents (Jun et al. 2021). Using existing ratios, Vrtagi et al. (2021) presented an advanced fuzzy weighted model and ranking system. Recent research comparing AHP, fuzzy AHP, permutation, TOPSIS, and fuzzy TOPSIS with road safety factors has demonstrated that the first three methods have similar results, but TOPSIS and fuzzy TOPSIS differ from the other methods (Sarraf and McGuire 2020).

As well as infrastructure, traffic was also used as a primary parameter, and the weighted aggregate sum product assessment method and hybrid model (Asadamraji et al. 2024) was used for ranking (Nenadic et al. 2019). Also MCDM problem-solving methods were used to evaluate factors such as geometry, traffic accidents, etc. for each sub-segment. This study also used FUCOM and MARCOS methods to identify the riskiest segments (Blagojevic et al. 2021). Using a hybrid model based on a module of prediction, Ali Mansourkhakie et al. (2016) attempted to increase the accuracy of the prediction model by using prior accident information. An analysis of mountain roads in China tried to reduce the reliance on environmental monitoring data. To do this, they developed an attribute reduction algorithm to make a systemic analysis method and proposed a risk analysis model. According to their results, this model can be used to assess mountain road safety (Jian Jun Wang and Xu Dong Cao 2021). Economic parameters have been added to the mentioned parameters in some studies. Bayrak and Bayata (2020) applied multi-criteria decision-making with simulation and focused on economic parameters as well as safety considerations. Also Models such as regression and Poisson have been used in the influence of road parameters such as shoulder width and lane width and other geometric characteristics in suburban road accidents (Mirzahosein et al.2023).

The research gap is the combination of proactive and reactive data. Usually, studies have emphasized only one of these two types of data, and the simultaneous combination of proactive and reactive data was not used much. Also, the hybrid model, which is a combination of the three methods proposed in this research, was not used in the studies for prioritizing the safety index.

By considering six criteria, including accident abundance, roadside condition, vertical and road markings, pavement condition, and access density, the present study proposed a model for ranking the safety of suburban roads. Accordingly, the initial section of the Sanandaj-Kermanshah road (i.e., Kurdistan and Kermanshah) was examined for traffic and accidents. We divided the route into segments and collected proactive data. Due to the lack of consensus among experts on a specific prioritization method, an indicator was proposed using EDAS (Keshavarz Ghorabaee et al. 2015) and CODAS (Keshavarz Ghorabaee et al. 2016) and simple weighting methods. Safety risk and budget were prioritized based on this indicator and the index of fatal and injury accidents.

2 Method

Safety audits and field activities are required for most road safety-related activities. By identifying problems and reviewing accident statistics, the information in this study was derived from the road and the segment under study. Organizations and departments responsible for road safety as well as experts and specialists' opinions were used to select the parameters.

2.1 Data

To begin the safety audit operation and gather proactive data, field survey forms were designed with general characteristics such as road name, mileage, inspection time, inspector name, as well as the characteristics of the surveyed points such as location and factors affecting accidents in order to analyse and reach the desired result. Moreover, reactive data (fatal and traumatic accident data from the last three years) was taken into account. In order to analyze fatal and injury accidents, we analyzed the databases of the Road Safety Commission and the national traffic police.

2.2 Criteria

In order to assess the safety of road sections, the following criteria were used:

- Accident history: Based on the number and severity of accidents over a specified period of time, a road's safety level was determined. In order to identify high-risk road situations, previous accident data (usually 1–3 years) were used. However, it should not be assumed that the area is low-risk just because no accidents have occurred at the road, as other factors may increase the risk of the region (Kar and Blankenship 2010).
- Access and intersections density at the road segment: Road accidents are more likely to occur when direct access to road scan is available. According to previous studies, a road with 10 accesses per kilometer may increase accident rates by 75% compared to the same road with 4 accesses per kilometer (McElhinney et al. 2010). Placement of accesses can also increase accidents, however.
- Present serviceability index: There is a correlation between accident rates and road surface characteristics such as friction and texture (Ouyang et al. 2020). While friction creates the necessary connection between tires and road surfaces, pavement surface prevents cars from losing their balance, especially in rainy conditions. The texture of the pavement can also create friction (Jones 2013). Moreover, grooves and roughness on the road surface can reduce slip resistance. Friction was applied using the current serviceability index, which ranges from 0 to 5.
- Vertical signs problems: Road safety depends on vertical signs, such as warning signs, guidance signs, and regulation signs.
- Road marking problems: Research has shown that clearing road markings can increase the number of accidents by 8–50% (Park and Young 2012).
- Problems with roadside obstacles: The presence of fixed obstacles along the roadside or on the road can increase the risk of accidents (Ayenachew et al. 2021).

2.3 Segments Risk Safety Prioritization Pattern

To rank road segments according to their safety, the following steps were taken:

2.3.1 Step 1: Determining Road Segments

This step specifies the length and number of segments. There were several equal sections on the road. In terms of length, the last segment may be shorter or longer than the others.

2.3.2 Step 2: Determining The Evaluation Criteria

Based on previous studies, Road Maintenance and Transportation Organization criteria, and expert opinions, the following criteria were defined for assessing safety:

- Criteria extracted based on the previous literature: Accidents that result in fatalities and injuries, vertical signs, road markings, and pavement condition.
- Experts' criteria based on field visits to the Road Maintenance and Transportation Organization: access density and roadside conditions.

2.3.3 Step 3: Road Safety Audit (proactive Data)

The purpose of this section is to perform a road safety audit. Therefore, safety audit evaluation criteria should be collected. Safety audits record all specifications of hazardous points.

2.3.4 Step 4: Collecting Statistics On Accidents With Injuries And Fatalities (Reactive Data)

Statistics on accidents are usually collected in three forms: damage, injury, and fatality. It is important to note, however, that damage accidents are not adequately recorded in Iran, and safety indicators are usually determined based on fatalities and injuries, accident severity index was defined based on Eq. 1.

$$R_a = \frac{N_f}{N_j + N_f} \tag{1}$$

Ra: Accident severity index.
Nf: Number of fatal accidents.

2.3.5 Step 5: Prioritizing Suburban Road Safety Risk

There was no consensus among experts regarding the choice of the prioritization method according to the literature review. By combining two relatively newer methods and a simple old method for determining the priority of segments safety risk, this study proposed an innovative index. There are a number of multi-criteria methods in use today, including EDAS, CODAS, and the old simple additive weighting method (SAW).

EDAS (evaluation based on distance from average solution) determines the best solution based on distance from the average solution (AV). This method does not require calculating the positive and negative ideals. To evaluate the desirability of options, two criteria are used: the positive distance from the average (PDA) and the negative distance from the average (NDA). EDAS should consider the weight and nature of the criteria, as well as the decision matrix. The parameters of the EDAS method are determined by Eqs. (2)–(6) (Keshavarz Ghorabaee et al. 2015).

$$SP_i = \sum_{j=1}^{m} W_J PDA_{ij} \tag{2}$$

$$SN_i = \sum_{j=1}^{m} w_J NDA_{ij} \tag{3}$$

$$NSP_i = \frac{SP_\imath}{\max(SP_i)} \tag{4}$$

$$NSN_i = 1 - \frac{SN_i}{\max(SN_i)} \tag{5}$$

$$AS_i = 0.5(NSP_i + NSN_i) \tag{6}$$

SP_i and SN_i: weighted sum of distance from average of alternatives.
NSP_i and NSN_i: normalized value of SP_i and SN_i.
AS_i: appraisal scor of sections.

The CODAS model, being a dual control model, incorporates both the Euclidean distance and the Taxicab distance. The optimal choice in this approach is the one furthest from adverse factors. Initially, the Euclidean distance is applied, followed by the Taxicab distance. These metrics are computed relative to the negative ideal point. Any alternative displaying the maximum separation from the negative ideal point is deemed most favorable within the CODAS methodology.

The simple additive weighting method uses a linear increment function for representing the decision makers' preferences. However, this technique is used when the preferences are assumed as independent. This method only requires the decision matrix and the weight vector of the evaluation indicators. Figures 1 demonstrate a step-by-step diagram of the used multivariate methods.

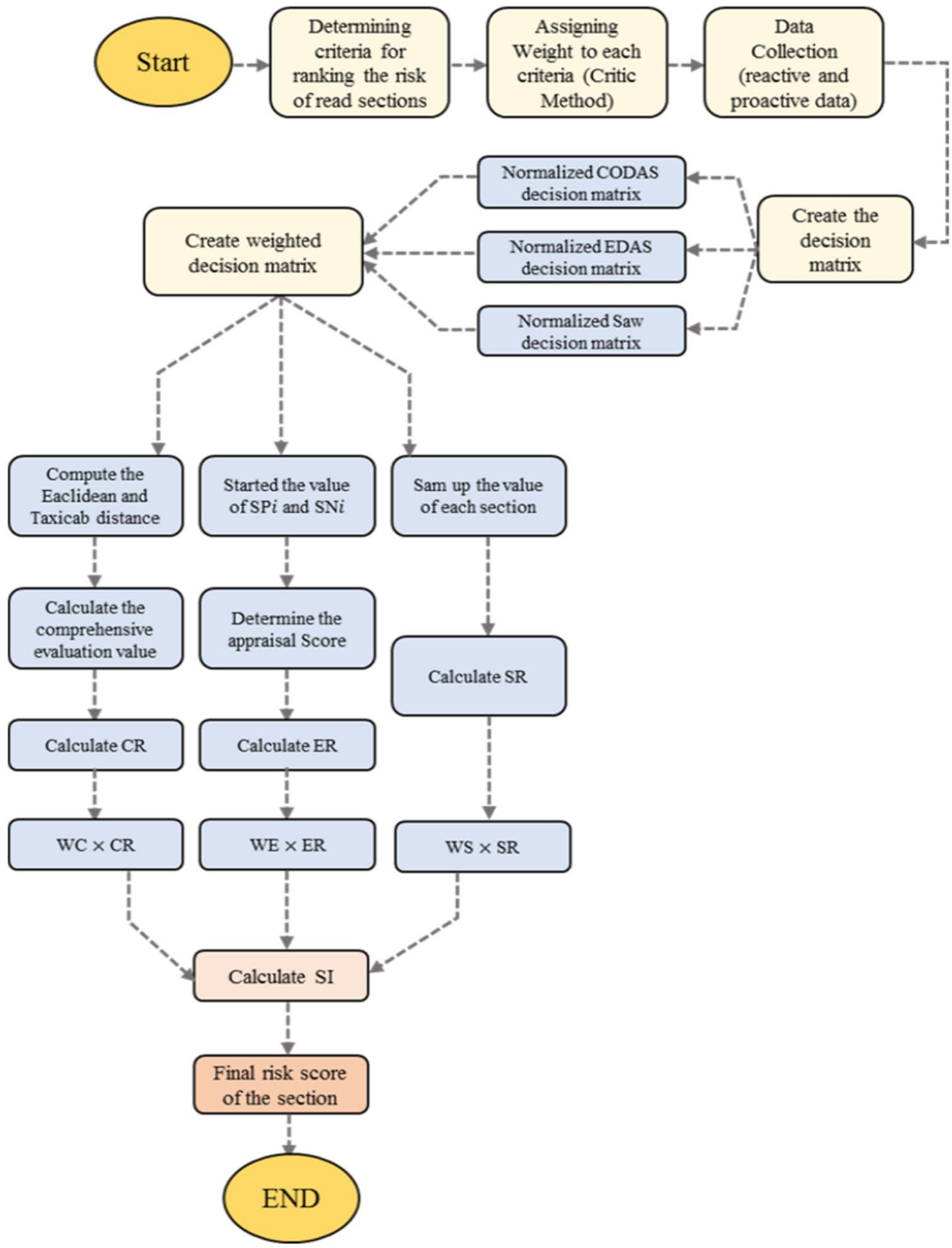

Fig. 1 Step of procedure to safety risk ranking of road section

2.4 The Proposed Index For Prioritizing The Safety Risk Of The Suburban Road Segments

Hybrid decision-making methods were combined based on Eq. 7 for determining the safety risk of the suburban road segments (Formula 7 is obtained through polling with elites).

$$SI = W_E ER + W_C CR + W_S SR \tag{7}$$

SI: Segment safety risk prioritization index.
ER: Segment safety risk rating with the EDAS model.
CR: Segment safety risk rating with CODAS model.
SR: Segment safety risk rating in the simple additive weighting.
Method.
WE: EDAS weight.
WC: CODAS weight.
WS: SAW weight.

The weights of the methods in Eq. 2 are obtained through the normalized weight of the probability of an accident and the risk rating of sections.

3 Findings

An evaluation of the proposed step-by-step method and a practical examination of the proposed index were conducted on the Sanandaj-Kermanshah road..

3.1 The Study Range

One of the most important access routes to Kermanshah Province is the Sanandaj-Kermanshah road (Fig. 2).

The route shown in Fig. 2 is connected to Kurdistan Province on one end and continues to the border with Kermanshah Province. This road, which is a part of the above mentioned road, is located in Kurdistan Province. In light of the fact that 60% of driving accidents occur within 30 km of cities, a 30 km long segment adjacent to Sanandaj has been selected and is divided into six segments of 5 km each.

3.2 Determining The Weight Of The Criteria

The weight of the criteria was obtained using critic method (Table 1). The CRITIC method is a technique for assigning weight to the criteria by considering the correlation and standard deviation of the data in the decision matrix and uses the linear normalization approach. In terms of performance, this method has similarities with the Shannon entropy method, however, this method does not rely on data dispersion.

Based on the steps presented in Fig. 1, the problem of segment prioritization for performing immunization was solved by using the EDAS method, which began with a decision

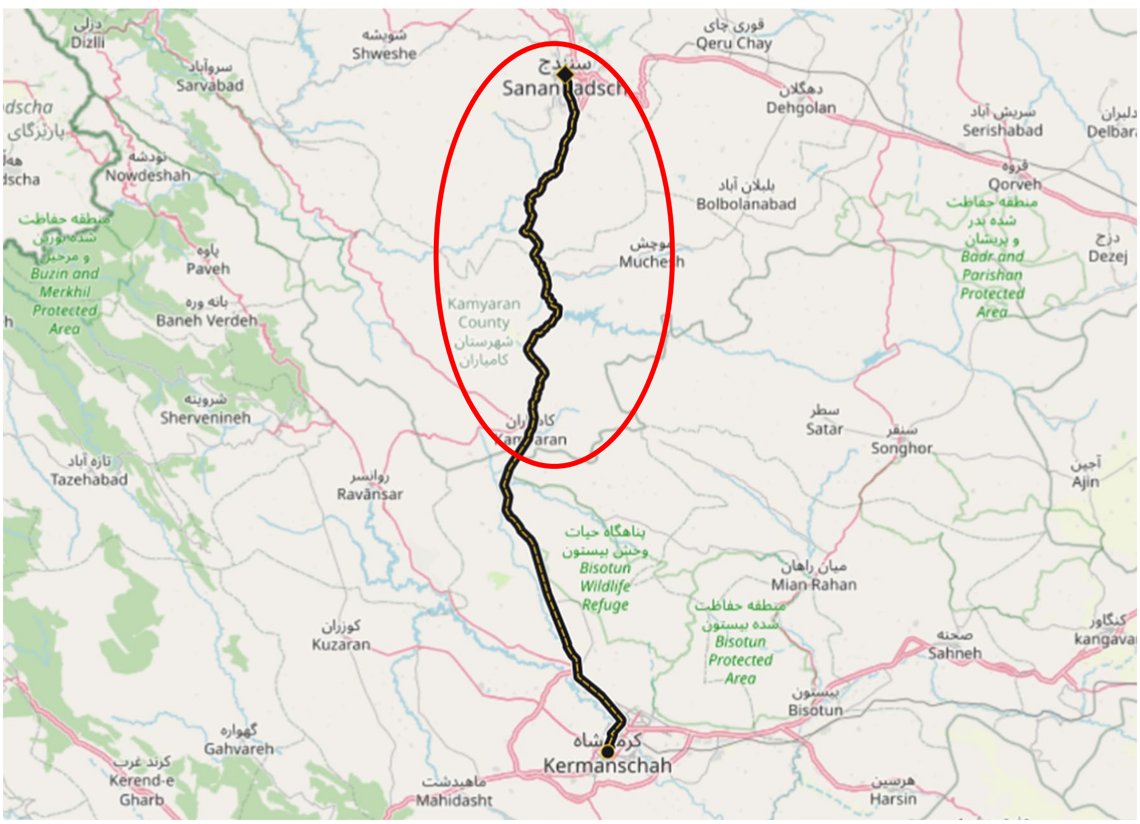

Fig. 2 Map of Sanandaj road to Kermanshah and the study area

Table 1 Weight of road safety risk prioritization criteria

Criteria	Accident severity index	Present serviceability index	Problems related to vertical signs	Problems with road marking	Defects in roadside guards	Density of access
Type	Positive	Negative	Positive	Positive	Positive	Positive
Weight	0.45	0.2	0.05	0.05	0.05	0.2

Table 2 Decision-making matrix

Criteria / Sections	Defects in roadside guards	Problems with road marking	Problems related to vertical signs	density of access	Present serviceability index	Accident severity index
0–5 km	2	0	1	15	4	0.19
5–10 km	0	1	2	8	3	0.26
10–15 km	3	0	0	12	3	0.24
15–20 km	0	0	0	7	4	0.31
20–25 km	1	0	0	10	3.5	0.19
25–30 km	7	0	0	14	3	0.17
Average	2.167	0.167	0.5	11	3.417	0.227

Table 3 Prioritizing safety actions in 6 segments of studied road (EDAS)

Road sections	*ER*
0–5 km	5
5–10 km	1
10–15 km	3
15–20 km	2
20–25 km	4
25–30 km	6

matrix based on the collected data (Table 2). According to Table 2, the index of average fatal and injury accidents had higher eigenvalues, indicating that pavement condition and access density were more important. Then, the positive and negative distances from the average value were calculated. As shown in Table 3, each distance has a different value. Calculated values were used to calculate and present SP and SN values. This step weighted the values calculated in the previous step. The calculated values and maximum sum of the rows were used to normalize the data and prioritize the selections. The normal values of NSP and NSN can be used to calculate ASi based on Fig. 3, which shows a direct relationship between the values and the risk of the segment.

Table 3 presents the rank of ER segments by considering the ASi value.

CODAS was used to solve the problem of segment prioritization in this section. Forming the decision matrix is the first step in this method. Unlike Table 2, the CODAS method specifies the minimum and maximum values of the columns for normalization in addition to the decision

Table 4 Euclidean distance and taxicab distance for all road sections

Distance / Sections	Euclidean distance	Taxicab Distance	Euclidean distance
0–5 km	0.113	0.161	0.113
5–10 km	0.149	0.244	0.149
10–15 km	0.131	0.218	0.131
15–20 km	0.203	0.203	0.203
20–25 km	0.054	0.090	0.054
25–30 km	0.106	0.143	0.106

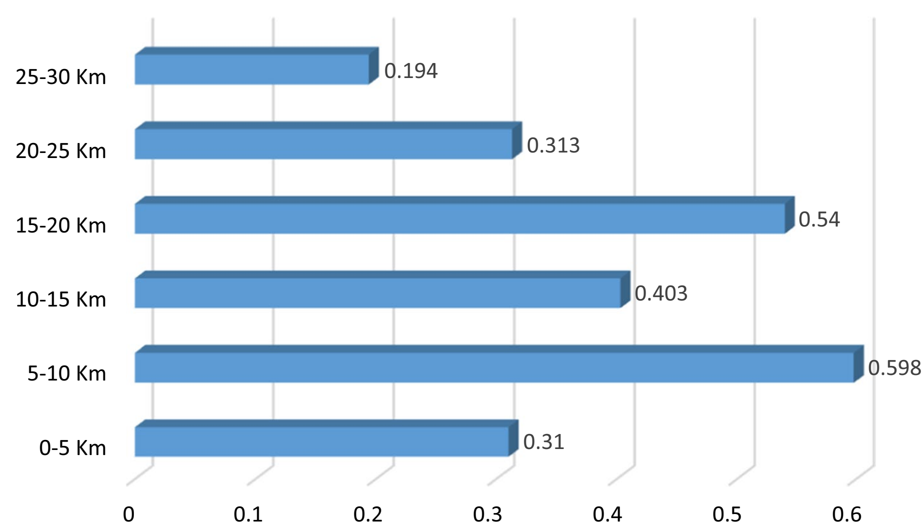

Fig. 3 Calculated AS_i for 5 km segments of Sanandaj- Kermanshah road using EDAS method

Table 5 Prioritizing 6 segments of studied road (CODAS)

Road sections	H	CR
0–5 km	−0.270	4
5–10 km	0.124	2
10–15 km	−0.056	3
15–20 km	0.202	1
20–25 km	−0.846	6
25–30 km	−0.349	5

Table 6 Section ranking by SAW method

Road sections	Ranking criteria (sum of rows)	*SR*
0–5 km	0.665092	5
5–10 km	0.784086	1
10–15 km	0.729816	2
15–20 km	0.693333	3
20–25 km	0.587711	6
25–30 km	0.683441	4

matrix. In this road, each element's value is divided by its maximum value, except for the present serviceability index. For the present serviceability index values, the minimum value of the relevant column should be divided by the other columns. The weights of each criterion were multiplied by the normalized matrix after normalizing the decision. Afterward, the distance from each point to the negative ideal was calculated, followed by the Euclidean and taxicab distances (Table 4).

In the final step, Eq. 8 was used for selecting the option with the highest risk.

$$Hik = (Ei - Ek) + (\Psi(Ei - Ek) \times (Ti - Tk)) \tag{8}$$

$$\psi(x) = \begin{cases} 1 & |x| \geq \tau \\ 0 & |x| < \tau \end{cases}$$

The value of the parameter ψ was determined based on the value of the threshold τ, which Eigen values was equal to 0.02. In general, the higher the H value, the higher the priority of the given option. The segment priorities are shown in Table 5.

The CODAS method indicates that the fourth segment has the highest priority for safety measures, while the first segment has the lowest.

For prioritizing safety risks for immunization, the simple additive weighting method was used. The first step in this method was to create a decision matrix (Table 4). As with CODAS, this method also normalized variables and used a weighted normal matrix. As a result of forming a weighted matrix and summing the rows, each road segment was ranked according to its safety risk (Table 6).

Table 7 The weight of the initial methods

Method	EDAS	SAW	CODAS
Type	Positive	Positive	Positive
Weight	$W_E = 0.34$	$W_S = 0.09$	$W_C = 0.57$

Table 8 Prioritizing 6 segments of studied road using proposed index

Road sections	Safety risk priority	*SI*
O–5 km	4	4.43
5–10 km	2	1.57
10–15 km	3	2.91
15–20 km	1	1.52
20–25 km	6	5.32
25–30 km	5	5.25

According to the SAW method and Table 6, the highest and lowest priorities for safety measures in the studied road were related to segments 2 and 5, respectively.

For determining the proposed index for prioritizing the safety risk of the road segments, each weight of the initial prioritization models should be determined. Therefore, the three methods were normalized based on their probability of predicting an accident in 5 km parts. (Table 7).

Table 7 shows that the CODAS method has the highest weight due to Euclidean distances and taxicab distances being considered. Table 8 and Eq. 2 were used to calculate the safety risk index for 5 km segments of Sanandaj-Kermanshah road (Table 8).

The lower the SI value, the higher the priority for safety measures related to the segment's safety risk. Safety promotion measures should be taken for the fourth and second segments, based on the proposed index.

4 Discussion

Inspections and audits of road safety can help identify problems and improve road safety at different stages (Sun et al. 2006). By analyzing tunnels and accident statistics, Rossetti et al. (2014) conducted safety audits and safety audits. A simultaneous examination of reactive data and proactive data in risk assessment was demonstrated by the results of the present study. Budget allocation decisions were based on road safety audit (proactive) data from the operation phase.

Form design and safety audit method were in accordance with international standards and methods used by developed countries, such as Europe, the USA, and Canada. There is a significant difference between this research and the activities performed in the type of criteria selected and their effect on the prioritization model.

Using a hierarchical analysis model, Najibet al. (2012) identified speeding, vision, and distance problems, brake and tire defects, roadblocks, and movements in the opposite direction as accident causes. As part of the present study, environmental and road factors were considered as the most important factors, and the average accident severity index was also taken into account. It can be stated that the statistics of accidents that occurred and safety audit data that increase the probability of accidents were used according to Iranian conditions. In this study, hierarchical analysis was used only in the criteria weighting stage, and the three important methods (CODAS, EDAS, and simple additive weighting methods) were combined to prioritize the segments.

There is a similarity between the composite index of Hermans et al. (2008) and the one in the present study in that both use a simple additive weighting method. With the introduction of newer multi-criteria decision-making models, taxicab and Euclidean distances, as well as the average, were also used in the present IR index, suggesting its advantages. Hermans et al. (2008, 2009) found that data envelopment analysis was a better method, contrary to our findings. In 2008, Antik et al. re-identified data envelopment analysis as an appropriate method for prioritization.

Previous studies have shown that there is a significant relationship between road audit parameters and accidents, and the risk of safety of road segments is essential considering these factors, which was confirmed by the results of research conducted in Utah, USA (Jones et al. 2013).

Research conducted in the past has similar and different results from the present study. Using geometric and traffic parameters of intersection areas, Yakar (2021) study focused only on intersections and accesses. For this study, however, the entire road segment, including the access area and inter-intersection, was considered, and weighting was also considered in two stages with different populations.

The main difference between the results of the proposed index in this paper and past studies (e.g., Moslem et al. (2020), Nenadic et al. (2019), Fancello et al. (2019), Bathrinath et al. (2021), and Vrtagić et al. (2021) is related to the type of models and weighting method. As a result of the uncertainty results of the fuzzy models used in Moslem et al. (2020), a simple two-step weighting method was used in the present study. According to the author, taxicabs and Euclidean distances as well as their combination are more effective in prioritizing safety risk issues in the current situation. CODAS evaluates sections in two steps. The Euclidean distance is used to calculate the distance of the options from the negative ideal. A threshold function determines the relative proximity of the sections in this step. After calculating the Euclidean distance.

5 Conclusion And Recommendations For Future Research

The most important causes of traffic accidents were roads and their surrounding environment, as well as existing infrastructure. By securing the roads and solving their problems, many problems can be solved and a large number of accidents can be prevented. According to previous studies, about a third of accidents are caused by road factors alone or in combination with other factors. Safety audits can help reduce accident hotspots on the roads and determine timely safety measures. Field visits were used to collect statistics and safety audit information for this study. By collecting information through safety audits as well as accident data and weighting them from the methods proposed in this study, this method can be extended to other roads (This model is applicable for any number of road parts and any kind of road conditions). Of course, it should be noted that the collection of information must be specific to the same road. The road police also collected statistics and information about injuries and fatalities in addition to safety audits. An index of safety risk was proposed in this paper, based on the field visit and statistics regarding injuries and fatal accidents for allocating budget and safety enhancements, especially in the context of budget shortages, based on the safety risk rate in segments of suburban roads. The following results were obtained for the safety measures and their implementation on a suburban road based on the index suggested for safety risk of road segments: In the evaluations, previous studies, and pairwise comparisons, the average number of fatal and injury accidents was the most important factor in determining the rank of segments, followed by access density with a weight of 20%, and other factors such as symptoms and side effects. Although all multivariate problem-solving methods can lead to the solution and priority, combining methods can increase the accuracy of the response. Therefore, the negative effects of methods with lower accuracy would be reduced, while the positive effects of methods with higher reliability would be amplified. Furthermore, it can increase public and manager acceptance of safety measures regarding road segments. Also When evaluating and prioritizing segments, it is important to consider whether the criteria are positive or negative, since this can change the risk of safety points. Due to the fact that the criterion for selecting segments is their higher risk, all selection criteria in this study, except for the pavement performance index, were taken into account, including the average number of fatal and injury accidents, access density, vertical sign and road marking problems, and sideguard issues. The greater the number, the greater the segment risk, but the higher the pavement quality, the lower the segment risk. A segment with a higher risk should take immediate safety measures given the ranking of the points. Also Safety measures are prioritized in different segments of the road, which indicates the priority of allocating funds to these segments under budget constraints. While segments closer to the cities of origin and destination had more traffic and accidents, the patterns of accident frequency, severity, and safety rating differed in some roads. Road accidents and injuries could be drastically reduced if safety measures are taken earlier in higher-rated segments. Due to the fact that the accident index is severity, the impact on the severity of the accident is greater.

The results of this study can be used by road managers and operators to improve and secure roads. The number of segments and criteria could be expanded in this model.

An economic model can be developed for allocating budgets for security measures in the future. Further, intelligent safety promotion equipment could be used to compare the segments. Other hybrid indicators and multi-criteria decision models could also be proposed. Furthermore, road accidents could be assessed after performing safety measures according to the priorities outlined in this study. As a final suggestion, other segments of the Sanandaj-Kermanshah road should be examined in the ranking patterns and compared with the segments of the first 30 km of the Sanandaj-Kermanshah road examined in this study.

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