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PRIORITIZATION ROAD SAFETY STRATEGIES TOWARDS ZERO ROAD TRAFFIC INJURY USING ORDINAL PRIORITY APPROACH

Mouhamed Bayane Bouraima [1, 2, 3], Clement Kiprotich Kiptum [4], Kevin Maraka Ndiema [4], Yanjun Qiu [1, 2*], Ilija Tanackov [5]

[1] School of Civil Engineering, Southwest Jiaotong University, China
[2] Highway Engineering Key Laboratory of Sichuan Province, Southwest Jiaotong University, China
[3] Organization of African Academic Doctors (OAAD), Nairobi, Kenya
[4] Department of Civil and Structural Engineering, School of Engineering, University of Eldoret, Kenya
[5] University of Novi Sad, Faculty of Technical Sciences, Novi Sad, Serbia

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Research paper

Abstract: Road traffic safety has emerged as an urban mobility and development issue for African cities throughout time. To establish a comprehensive road safety reform within cities, one needed to be familiar with the political and legal environment, institutional responsibilities, and stakeholders. Road safety reform, though, is not without its issues. This study aims to prioritize Nairobi's road safety strategies to achieve zero traffic injuries. Four road safety reform challenges were examined based on the opinions of three experts. The Ordinal Priority Approach (OPA) was used to calculate the weights and ranks of experts, alternatives, and criteria, simultaneously. The findings of the study indicated that lack of political priority given to road safety reform is the most significant challenge, while the lack of coordination among different government agencies is the least challenge. The findings of the study also indicated that the top three strategies for successfully enacting a road safety reform are to take advantage of broad institutional and governance reform, reframe the road safety in political and public debate, and bundle the road safety with other important public issues.

Key words: *Prioritization, road safety strategy, zero traffic injury, Ordinal Priority Approach*

* Corresponding author.
mouba121286@yahoo.fr (M.B. Bouraima), chelalclement@yahoo.com (C. K. Kiptum), marakakevin@yahoo.com (K. M. Ndiema), publicqiu@vip.163.com (Y. Qiu), ilijat@uns.ac.rs (I. Tanackov)

1. Introduction

Every year, approximately 1.3 million people are murdered and 50 million are injured in road traffic accidents (Gopalakrishnan, 2012). Over 90% of road traffic accidents (RTAs) occur in the low and middle-income countries (LMICs), with Africa having the highest death rate (Alimo, Agyeman, Sumo, Bouraima, & Lartey-Young, 2022; Das, 2022), and an indicator ranging from 25 to 34 per million people (Mohammed, Ambak, Mosa, & Syamsunur, 2019).

In the recent decade, road safety has also become a major international concern. Two road safety targets are included in the 2030 Agenda for Sustainable Development: target 3.6 by 2020 and target 11.2 by 2030. According to current projections, neither target is likely to be met. In terms of tackling road safety issues, some countries have been significantly more effective than others. In locations where significant progress has been made, the importance of a comprehensive approach to road safety cannot be overstated (Welle et al., 2018). Road safety is considered as a public healthy lifestyle that emerges from the interaction of all transportation system elements, including habitat usage, vehicle standards, emergency services, law, roadside design, modes of transportation, and other variables. Despite all of the acquired knowledge about what such a "Safe System" appears like, establishing and adopting it continues to be a major challenge for many countries, particularly LMICs.

As the number of deaths in developing countries continues to rise (Bener, Abu-Zidan, Bensiali, Al-Mulla, & Jadaan, 2003), and road traffic collisions continue taking an incredibly huge social and financial cost burden, it is crucial to assess and fully comprehend what is adversely obstructing progress and what might be done to prevent these statistics. Sharpin, Harris, Dempster, and Menocal (2018) have conducted a study project to assess the obstacles to road safety improvement in LMICs, as well as to develop a set of strategies to assist policy-makers and practicians working on road safety improvement. The initiative started with the research of Wales (2017) that looked at the broad scope of the problem, the main aspects of the global response, and the current state of evidence on interventions to respond to the challenges. The study found a lack of particular emphasis on the challenges linked with road safety reform, as well as a knowledge gap about how improvement strategies should be prioritized for an effective implementation.

Nairobi, among other cities, was chosen for a more extensive case study examination to close this gap. A thorough assessment was carried out in partnership with local partners, based on a review of the city's injuries, fatalities, and collisions, the major actors involved in handling road safety, as well as the challenges and prospects for development. The outcomes of this study report revealed both road safety challenges and strategies for eradicating them.

Past studies related to road safety challenges and remedial strategies are presented in Table 1. As can be seen from the Table 1, very few researchers have identified the road safety challenges and remedial strategies in Africa (Bezabeh, 2013; Khayesi & Peden, 2005; Martin & Tawia, 2020). Additionally, only one study has discussed Kenya's road safety strategies and challenges without providing any proposals for the most efficient strategies to use to address these challenges (Sharpin et al., 2018). Moreover, these studies have not applied the multi-attribute decision making (MADM). Without a relevant exceptional system, an accurate pinpointing and classification of challenges and remedial strategies for road safety could not be

reached. So, the findings of these previous incomplete investigations could not give the required details for policy-makers to ameliorate road safety reform for zero road traffic injuries. Based on the previous studies, an acute shortage of documentation exists about the uncertain prioritization of remedial strategies. A research gap remains in handling extensive research by taking into account both qualitative and MADM methodologies. By integrating the MADM method and qualitative investigation, this study intends to answer this research gap accurately. In this study, a methodology for an extensive examination of road safety challenges and prioritization of remedial strategies in Nairobi is presented based on the ordinal priority approach.

In this study, we will prioritize the road safety improvement strategies for Nairobi according to the decision criteria for experts to have an implementation scheme. Six strategies (alternatives) are taken into consideration for this reason. These strategies are evaluated based on four main criteria. The criteria are established based on the report of Sharpin et al. (2018) titled: "Securing safe roads: The politics of change" and confirmed with the assistance of professionals in the field. The strategies are also displayed in the same report.

This study uses the Ordinal Priority Approach (OPA) recently developed by Ataei, Mahmoudi, Feylizadeh, and Li (2020). OPA method gives a new multiple attribute decision-making (MADM) scheme for dealing with road safety improvement based on prioritization strategies towards zero road traffic injuries. As a result, the following are the study's main contributions and novelty: (1) The OPA can define the weights of experts, attributes, and alternatives concurrently without the need for normalization, pairwise comparisons, or information perfectness (Pamucar, Deveci, Gokasar, Tavana, & Koppen, 2022); (2) To address the issue of a limited selection of specified scales in traditional techniques for a similar evaluation of criteria (Alosta, Elmansuri, & Badi, 2021; Badi & Abdulshahed, 2019; Bouraima, Qiu, Yusupov, & Ndjegwes, 2020; Bouraima, Stević, Tanackov, & Qiu, 2021; Kovač, Tadić, Krstić, & Bouraima, 2021; Stevic, Badi, Tanackov, & Milicic, 2017; Stević et al., 2022); (3) This is the first study to look at the prioritization of road safety improvement strategies in Nairobi, to achieve zero road traffic injuries. In addition, four main criteria are defined to provide a feasible framework for effective prioritization of relevant strategies; (4) This research offers recommendations for choosing the best strategy for achieving zero road traffic injuries as part of the road safety improvement; (5) The OPA enables policymakers to choose the most appropriate road safety improvement strategy, successfully respond to road safety challenges in Nairobi.

The research goals of this study are as follows: (i) to give an implementation framework for road safety improvement towards zero traffic injuries (ii) to examine the ordinal priority approach in the prioritization of road safety improvement strategies (iii) to use an example of road safety improvement strategies for zero traffic injuries in Nairobi for the applied method. By doing so, the study will answer three subsequent questions: (*) What is the framework to be implemented for road safety improvement towards zero traffic injuries? (**) What is the most challenging factor impeding the road safety reform? (***) What are the best strategies to be implemented for an effective of road safety reform?

Table 1. An overview of available research works in the field of road safety challenges and remedial strategies prioritization

Authors	Location	Discussion on challenges/ risks	Discussion on strategies	Prioritization of safety reform strategies
Odonkor, Mitsotsou-Makanga, and Dei (2020)	Sub-Saharan Africa	√		
Agerholm and Andersen (2015)	Denmark	√		
Martensen et al. (2019)	Europe	√		
Bliss and Breen (2012)	Developing countries	√		
Oster Jr and Strong (2013)	United States	√		
Deme (2019)	Africa	√		
Hasson (1999)	OECD countries	√		
Bertin-Jones (2010)	Global	√		
Morgan (1999)	America	√		
Khayesi and Peden (2005)	Africa	√	√	
Martin and Tawia (2020)	Africa	√	√	
Dhliwayo (2000)	Southern African Development Community		√	
Dhliwayo (2007)	Africa		√	
Yannis et al. (2018)	Africa		√	
Bezabeh (2013)	Africa	√	√	
Mzee and Chen (2012)	Dar es Salaam		√	
Raynor and Mirzoev (2014)	Kenya	√		
Lamont and Lee (2015)	Kenya	√		
Sharpin et al. (2018)	Columbia, India, Kenya	√	√	
Our study	Nairobi (Kenya)	√	√	√

The rest of the paper is structured into the following sections. Section 2 presents the antecedent works on the applied method and the multi-criteria decision making (MCDM) usage for road safety evaluation. Section 3 introduced the steps of the suggested method. Section 4 deals with the methodology of the study based on data collection technique, collected data, and the framework of the prioritization of road

safety improvement strategies. In section 5, the results and discussion are shown. Lastly, the conclusions with further research directions and limitations are provided in Section 6.

2. Literature review

Two parts have characterized the literature section as shown bellows.

2.1. Studies applied the ordinal priority approach

The Ordinal Priority Approach (OPA) is firstly introduced by Ataei et al. (2020). After that, the benefits of their method have emerged in numerous studies such as the assessment of construction sub-contractors (Mahmoudi & Javed, 2022), suppliers for healthcare center assessment (Quartey-Papafio, Islam, & Dehaghani, 2021), agriculture sector (Islam, 2021), robot selection (Abdel-Basset, Mohamed, Abdel-Monem, & Elfattah, 2022), risk assessment (Sadeghi, Mahmoudi, & Deng, 2022), post-pandemic strategies (Le & Nhieu, 2022), and planning strategies prioritization (Pamucar, Deveci, Gokasar, Martínez, & Köppen, 2022).

2.2. MCDM on the road safety evaluation

In the context of road safety performance, a wide range of MCDM strategies has been suggested. Table 2 indicates various MCDM techniques that have been used in the road safety assessment.

Table 2. Recapitulation of road safety studies with application of MCDM

Authors	Country	Methods	Research topic
Ghram and Frikha (2020)	Tunisia	ARAS-H	Classifying the Tunisian governments based on road safety problem assessment
Farooq and Moslem (2020)	Hungary	ANP	Assessing driver behavior parameters concerning road safety
Chen, Zhu, Zu, Lyu, and Yang (2022)	Southeast Asia	CRITIC-ELECTRE-FCM	Evaluating road safety achievement
Omrani, Amini, and Alizadeh (2020)	Iran	DEA, BWM	Assessment of road safety
Farooq et al. (2021)	Hungary	AHP-BWM	Evaluation of considerable factors impacting frequent lane-changing
Zhu, Chen, Li, and Shuai (2021)	China	CEM, regret theory, WASPAS	Assessment of road safety performance
M. Khorasani et al. (2013)	European countries	AHP	Road safety performance evaluation
Sudha and Rajarajeswari	India	AHP	Road safety management analysis

(2012)			
Bao, Ruan, Shen, Hermans, and Janssens (2012)	European countries	Fuzzy TOPSIS	Road safety performance assessment
Zu, Peng, and Chen (2022)	European Union member states	CV, PROMETHEE	Supervision of road safety progress
Moslem, Farooq, Ghorbanzadeh, and Blaschke (2020)	Hungary	AHP, BWM	Assessment of driver's behavior factors based on road safety
Rosić, Pešić, Kukić, Antić, and Božović (2017)	Serbia	DEA, TOPSIS	Selection of optimal road safety composite
G. Khorasani et al. (2013)	European countries	SAW, AHP, Fuzzy TOPSIS	Assessment of road safety performance
Damjanović, Stević, Stanimirović, Tanackov, and Marinković (2022)	Montenegro	DEA, IMF SWARA, MARCOS	Traffic safety evaluation
Mitrović Simić et al. (2020)	Bosnia and Herzegovina	CRITIC, fuzzy FUCOM, DEA, fuzzy MARCOS	Road section evaluation
Stević, Das, and Kopić (2021)	South Africa	CRITIC, DEA, MARCOS	Traffic safety assessment
Our study	Kenya	OPA	Prioritization Road Safety Strategies

Note: Analytical Hierarchy Process: AHP; Analytical network process: ANP; Additive Ratio Assessment: ARAS; Best–Worst Method: BWM; Cross Efficiency Method: CEM; CRiteria Importance Through Intercriteria Correlation: CRITIC; Coefficient of Variation: CV; Data Envelopment Analysis: DEA; ÉLimination et Choix Traduisant la REalité: ELECTRE; Fuzzy C-Means: FCM; Improved Fuzzy Step-wise Weight Assessment Ratio Analysis: IMF SWARA; Preference Ranking Organization METHod for Enrichment of Evaluations: PROMETHEE; Technique for Order Preference by Similarity to Ideal Solution: TOPSIS; Weighted Aggregated Sum Product Assessment: WASPAS; Measurement of Alternatives and Ranking according to COmpromise Solution: MARCOS; Technique for order preference by similarity to the ideal solution: TOPSIS.

3. Ordinal Priority Approach method

In the present study, the OPA method is applied to evaluate the weights of the experts, and criteria, and to prioritize road safety improvement strategies for Nairobi

city towards zero road traffic injuries. This section briefly described the calculation steps of the OPA. Table 3 indicates the fundamental parameters of the method.

Table 3. Sets, indexes, and variables for OPA

Sets	
I	Set of experts $\forall I \in \mathrm{I}$
J	Set of criteria $\forall j \in \mathrm{J}$
K	Set of alternatives $k \in \mathrm{K}_{\forall}$
Indexes	
i	Index of the experts (1,….,p)
j	Index of preference of the criteria (1,……n)
k	Index of the alternatives (1,…..,m)
Variables	
Z	Objective function
$W_{ijk}{}^{k}$	Weight (importance) of k th alternative based on jth criterion by ith expert at k th rank
Parameters	
i	The rank of expert i
j	The rank of criterion j
r	The rank of alternative k

Following the subsequent studies of Mahmoudi, Deng, Javed, and Zhang (2021), and Ataei et al. (2020), the applicable steps of the OPA are presented below.

Step 1: Examining the challenging factors to the road safety reform.

Step 2: Definition of the ordinal preference of challenging factors.

Step 3: Formation of the linear model (1) according to the data collected from steps 1 and 2, and then solving of the model via an adequate software, Excel in our case.

Max Z

S.t:

$$
\begin{aligned}
& Z \leq i\left(j\left(k\left(W_{ijk}{}^{k} - W_{ijk}{}^{k+1}\right)\right)\right) \qquad \forall\, i,j \text{ and } k \\
& Z \leq \; ijmW_{ijk}{}^{m} \qquad \forall\, i,j \text{ and } k \\
& \sum_{i=1}^{p}\sum_{j=1}^{n}\sum_{k=1}^{m} W_{ijk} = 1 \\
& W_{ijk} \geq 0 \qquad \forall\, i,j \text{ and } k
\end{aligned}
\tag{1}
$$

where Z: Unrestricted in sign

After solving the model, Eqs. (2) to (4) are used to find out the weights of the alternatives, criteria, and expert (s). Eq. (2) must be used to find out the weights of alternatives, which are road safety strategies in the present study.

$$W_k = \sum_{i=1}^{p} \sum_{j=1}^{n} W_{ijk} \qquad \forall\, k \tag{2}$$

Eq. (3) should be applied for the determination of the weights of the criteria, which are challenges in the present study.

$$W_j = \sum_{i=1}^{p} \sum_{k=1}^{m} W_{ijk} \qquad \forall\, j \tag{3}$$

Eq. (4) should be applied for the determination of the weights of experts.

$$W_i = \sum_{j=1}^{n} \sum_{k=1}^{m} W_{ijk} \qquad \forall\, i \tag{4}$$

Uncomplicated steps are necessitated in the OPA method to find out necessary weights without the assistance of other techniques.

4. Research methodology

Based on the hierarchical framework in Figure 1, the data collection was obtained from three different experts. Six strategies were suggested to grasp sound technical reforms. These strategies were prioritized based on their impact on the remediation of the key challenges to road safety reform.

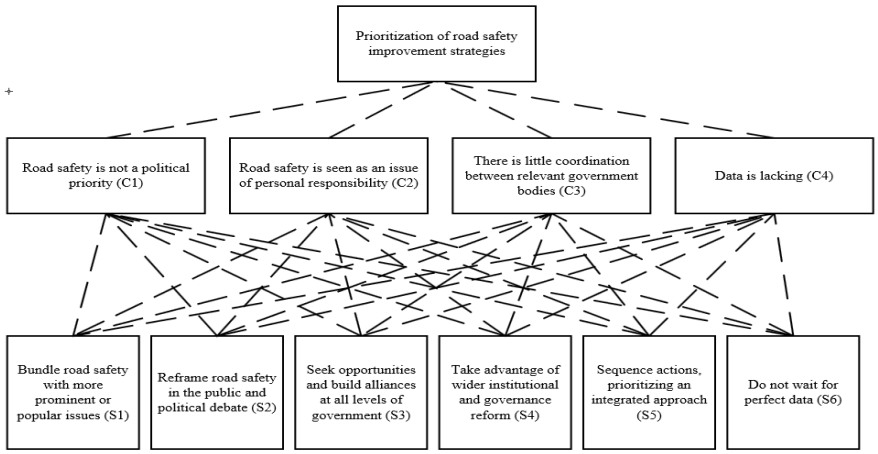

Figure 1. Prioritization of road safety improvement strategies based on key challenges

The three respondents were working at the Nairobi Metropolitan Area Transport Authority (NAMATA), the National Transport Safety Authority (NTSA), and at university, respectively. They have 10, 8, and 5 years of experience in road safety, respectively. Decisions by the experts were based on four criteria, namely road safety is not a political priority (C1), road safety is seen as an issue of personal responsibility (C2), there is little coordination between relevant government bodies (C3), and data is lacking (C4), where all the criteria are of beneficial criteria. Criteria have been ranked based on their degree of severity. First priority is given to the criteria that is more critical or that mostly challenge the road safety reform. For instance, in Table 4, expert 1 has given the first priority to C3. This means that C3 is the most challenging factor to the road safety reform according to his opinion. Meanwhile, C2 is the last priority for E1 (P4), this explains that C2 is the least challenging factor for road safety reform. The collection of data is presented in Tables 4 and 5. In these Tables, P1, P2, P3, P4, P5, and P6 signify priorities with P1 as the highest priority and P6 as the lowest priority. The prioritization of strategies will be done through the ordinal priority approach. The advantage of utilizing the model is that one can prevent the normalization of data, for instance, one can disregard which criteria were the higher-the-greater and which the lower-the-greater as the constituents are assessed according to their respective choice (Mahmoudi & Javed, 2022).

Table 4. Classification of criteria according to the judgment of three experts

	P1	P2	P3	P4
E1	C3	C1	C4	C2
E2	C1	C3	C2	C4
E3	C2	C1	C4	C3

Table 5. Classification of strategies based on the criteria by the three experts

		P1	P2	P3	P4	P5	P6
E1	C3	S4	S5	S3	S1	S6	S2
	C1	S2	S1	S3	S5	S4	S6
	C4	S6	S4	S3	S2	S5	S1
	C2	S1	S5	S6	S3	S2	S4
E2	C3	S4	S1	S2	S3	S5	S6
	C1	S2	S1	S4	S3	S5	S6
	C4	S6	S2	S1	S3	S4	S5
	C2	S2	S5	S4	S1	S3	S6
E3	C3	S3	S5	S4	S1	S2	S6
	C1	S2	S4	S5	S3	S1	S6
	C4	S6	S1	S2	S3	S5	S4
	C2	S6	S2	S1	S3	S4	S5

Note: “E” indicates expert. In this study, we have three experts: E1, E2, and E3.

5. Results and discussion

In this section, the weights of the three elements of the model namely experts, criteria (challenges), and alternatives (road safety strategies) were got using Eqs (2)-

(4). Then, they were classified in descending order, where lower weight indicates lower rank. The weights and ranking of the experts and criteria are shown in Table 6.

Table 6. The weights and classification of experts and criteria using the OPA

		Weight	Rank
Experts	E1	0.545454	1
	E2	0.272727	2
	E3	0.181818	3
Criteria	C1	0.349090	1
	C2	0.305454	2
	C3	0.149090	4
	C4	0.196363	3

As shown in Table 6, the most challenging factor remains the first criterion C1 (road safety is not a political priority) with a value of 0.349. Our findings are in accordance with the previous studies of Small (2014) and Odonkor et al. (2020) which indicate that the absence of political concern, interest, and priority is the main shortcoming of road safety management in Africa. The least significant criterion remains the third criterion C3 (little coordination between relevant government bodies). When considering the alternatives (strategies), exploiting broad institutional and governance reform strategy (S4) emerges as the best one followed by reframing road safety in the public and political debate (S2), and the strategy to bundle road safety with more important popular issues (S1), as indicated in Figure 2.

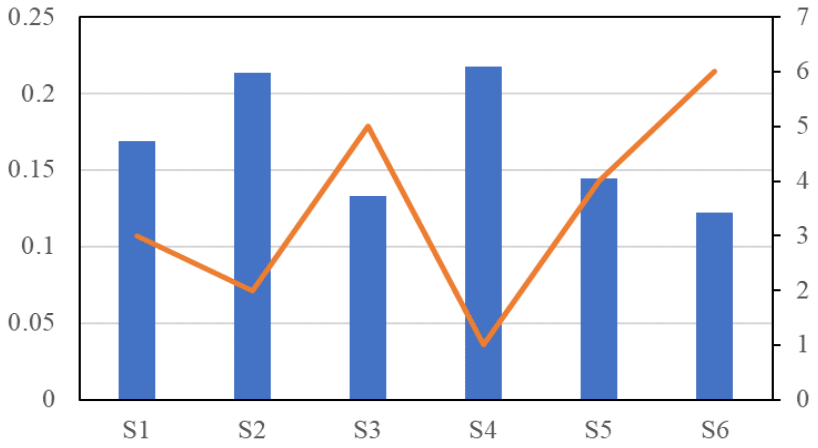

Figure 2. Proposal prioritization of road safety improvement strategies

7. Conclusion

In this study, the Ordinal Priority Approach is utilized to prioritize strategies for zero traffic injury based on challenges to road safety reform. As a result of the literature review, four criteria were used: road safety as not being a political priority, road safety being seen as an issue of personal responsibility, little coordination between relevant government bodies, and data lacking. The survey includes the opinions of three experts. The study's findings revealed that the road safety reform

as not being a political priority is the most challenging factor to road safety reform, followed by road safety as an issue of personal responsibility. The least challenging factor is the lack of coordination amongst various government bodies. According to the significance weights of the criteria and expert's opinions, exploiting broad institutional and governance reform is chosen as the best strategy, even though the improvement of road safety in Nairobi was proven to be difficult because of disintegrated responsibility or absence of ownership (Sharpin et al., 2018).

Given the negative effects of these challenges on road safety reform, it is first advised that Nairobi should improve its institutional cooperativeness and responsibility so that the public confidence in local institutions will be increased and a disposition to follow local regulations will be built. In addition, typical reforms to the transport department, city finances, police, and public transport should be implemented to boost Nairobi's city capacity to impact, administer and surveil the mobility and safety of people. Finally, the population should have the right to use the courts to mandate weakly coordinated institutions to take action on road safety. These recommendations can be implemented by the government ministries, departments and agencies (MDAs) in the road safety policy guidelines in Nairobi city. This study is practical for academicians, security agencies and the National Transport and Safety Authority (NTSA) officials and permits full and effective analysis of road safety reform.

This is the first study of its sort in Nairobi city, incorporating the use of multi-attribute decision-making to assess the most challenging factors to road safety reform and find out the best strategies to be implemented toward a zero-traffic injury goal. The implemented technique demonstrated how the criteria were reviewed without the need for a decision-making matrix or a pairwise comparison matrix, as well as the decision-maker's ability to only judge alternatives and attributes for which they have sufficient information and competence. Based on the application results, it can be said that the applied methodology is an efficient assessment procedure that policymakers and managers can use to make valuable inferences, proactive behavior for the challenging factor evaluation of road safety reform. As a result, the methodology presented here has the potential to be applied in a variety of circumstances.

The approach's most significant drawback is that it fails to account for situations in which experts have doubts about their judgment. Because of the more dynamic environmental conditions and the procedure requirement of incomplete and unclear information, the method can be extended in future studies by incorporating additional demands on mathematical approaches for multi-criteria optimization. The fact that only four criteria were considered, as well as the opinions of only three experts, is another shortcoming in this paper. Future research for in-depth analysis may take more criteria divided into political, institutional, legal, social, and economic groupings. In addition, the number of professionals with various backgrounds should be increased. Additionally, national research that considers other counties rather than just Nairobi City is required

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