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Evaluation of Factors Affecting Road Maintenance in Kenyan Counties Using the Ordinal Priority Approach

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Abstract: Improving Kenya's complete road network has been used to alleviate poverty and achieve the Vision 2030 goals. Roads enhance all areas of social development, including demand for and access to information, health, and education, in addition to poverty alleviation. However, the majority of Kenyan highways are plagued by a variety of maintenance concerns. This study aims to rank counties according to critical severity based on factors affecting road maintenance using an ordinal priority approach. Five challenges that could have an impact on road maintenance were looked at from the views of three decision-makers. The results of the study show that road materials are the least challenging aspect affecting road maintenance performance, while procurement practices are the most problematic. The studies also revealed that Nairobi County is most affected by these factors, whereas Nakuru County is least affected. In light of the findings, recommendations were made to assist both the government and the road sectors in dealing with these difficulties.

Keywords: ordinal priority approach, road maintenance, Kenya

1. Introduction

The most common form of transportation worldwide is by road. Roads are essential for reducing poverty and promoting global economic progress (Anyanwu & Erhijakpor, 2009; Bouraima & Dominique, 2018). Road degradation caused by a lack of maintenance has been a major source of concern in several developing countries (Gwilliam et al., 2008). Road maintenance is done to keep roads in good shape, even though they will unavoidably deteriorate due to weather and traffic over time. As consequence, after road construction, maintenance should start to reverse this deterioration (Burningham & Stankevich, 2005).

With 34% of all transport output in Kenya in 1998, road transport was the system that contributed the most to the country's output. Water transportation comes in second at 16%, followed by air travel at 25% (Ikiara et al., 2000). Given that this level of success was attained despite subpar road maintenance, it is clear that the sector, and therefore the policy on road infrastructure, has the potential to promote rapid economic growth and the eradication of poverty through its impact on employment, market access, and investment (Wasike, 2001). However, there is a problem that affects people all across the world: poor road maintenance.

Stević et al. (2022) claim that it is important to preserve a structure's serviceability and avoid any deterioration that could shorten its useful lifespan. There is rarely a budget setup for maintenance work, and it does not receive the attention it requires. To extend or at least maintain the serviceability of the infrastructure till the end of its lifecycle, maintenance is, however, the most important task to be completed.

The adoption of performance-based road maintenance contracting necessitates an investment of billions of shillings to support the Kenya Roads Board's mission to keep Kenyans connected by improving the country's road system. Even if Kenya's highway institutions will receive the funds and complete the planned road maintenance, some unfortunate situations affect the maintenance (Esaba, 2014; Kimeu, 2018; M'arimi, 2019; Maina, 2019; Njangu, 2015; Wambugu & Mburugu, 2017; Wambugu, 2017).

A summary of studies related to factors influencing road maintenance in Kenya is shown in Table 1. As can be seen, most of them focused on either a specific county or a particular region of Kenya (see Table 1). Also, the influential factors of road maintenance were examined using several quantitative approaches to assist decision-makers to make better resolutions about how to cope with the influential factors. These incorporated inferential

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Table 1
Summary of studies on influential factors of road maintenance in Kenya

Authors	Source of data	Sample	Method analysis	County/region
Kimeu (2018)	Questionnaire	216 respondents	Inferential statistics	Machakos county
Njangu (2015)	Questionnaire	145 respondents	Descriptive survey design	Meru county
Wambugu and Mburugu (2017)	Questionnaires and interview schedules	54 respondents	Regression analysis and cross-tabulation	Kisumu county
Kimeli (2016)	Questionnaires	360 respondents	Descriptive statistics	Uasin Gishu County
Esaba (2014)	Questionnaire and organization record	40 respondents	Descriptive statistics	Busia region
M'arimi (2019)	Questionnaires and an interview schedule	36 respondents	Descriptive study design	Central Region
Maina (2019)	Questionnaires and organization archives	86 respondents	Descriptive statistics	Nairobi Thika Highway
Limo (2012)	The questionnaire, interviews, and document reviews	90 respondents	Descriptive survey design	Western Region
This study	Questionnaire	3 respondents	OPA	Four counties

statistics (Kimeu, 2018), descriptive statistics (Esaba, 2014; Kimeli, 2016; Limo, 2012), and the combination of both inferential and descriptive statistics (M'arimi, 2019; Njangu, 2015). Kimeu (2018), for example, employed inferential statistics to establish how the project team's skills, financial viability, managerial support, and monitoring and evaluation influenced the performance of rural road maintenance projects. Respondents were selected using the stratified proportionate random sample technique, and primary data were obtained using self-administered questionnaires. The study's findings revealed that the project team's effectiveness had a stronger influence on rural road maintenance. Esaba (2014) investigated the variables influencing Kenya Rural Roads Authority's ability to maintain roads using a descriptive statistic. The primary and secondary data collection methods both make use of questionnaires and organizational records. The study's findings indicated that politicians have an impact on the selection of funded projects and the tendering process. The impact of funding, personnel expertise, and public involvement on the execution of performance-based road maintenance projects in Kenya's central region was examined by M'arimi (2019). A descriptive study design, which integrates both qualitative and quantitative methods, was used to collect and analyze data. According to the study's findings, personnel competence, public participation, and financial access all have a major impact on the execution of performance-based road maintenance initiatives. Limo (2012) used a descriptive survey study approach to investigate how the types of contractors, pricing and availability of materials, and the environment affect the cost of road maintenance. Njangu (2015) employs a descriptive survey approach to investigate the impact of cost, political, technological, and temporal factors on rural road network maintenance. The study's findings revealed that there is political involvement in the planning and budgeting of road improvements, that the technology used to complete the projects is insufficient for the volume of traffic in the area, and that the projects were not completed on time. Kimeli (2016) employed questionnaires as the major data collection instrument to investigate the factors influencing the flow of road network maintenance funding. Maina (2019) investigated factors influencing road maintenance in Kenya using a descriptive survey as part of its research design. His research found that the skill of project managers had the largest impact on road maintenance, followed by the availability of finance and finally community engagement. Wambugu (2017) investigated the impact of social and economic factors on bitumen road maintenance using a descriptive study approach. According to the study's findings, the availability of funds, followed by political leadership, had a substantial impact on bitumen road maintenance. Remarkably, none of the studies aforementioned suggested the implementation of the ordinal priority approach (OPA).

In the literature, the OPA has been extensively used. A novel risk assessment model based on the trapezoidal fuzzy OPA is put forward by Sadeghi et al. (2022) to examine the significance of organizational criteria, the effect of blockchain risks on criteria, and the likelihood that risk would materialize. They discovered that the "communication and information" of an organization is particularly vulnerable to blockchain risk. In contrast, the "social responsibility" of a corporation has little to do with blockchain. A useful conceptual framework is presented by Mahmoudi et al. (2022) for project-oriented firms to choose the best portfolio by their organizational resilience strategy. They used elbow and fuzzy C-means methods to firstly identify the project portfolios and cluster the projects based on the organizational resilience plan. The stakeholder feedback and the robust ordinal prioritization approach, which can handle the ambiguity of the input data, are then used to establish the projects' ratings. The best portfolio associated with the organizational resilience strategy is finally chosen once each portfolio's score has been calculated using the project scores that were acquired. The applicability and effectiveness of the new extended ordinal priority technique are proposed by Abdel-Basset et al. (2022) for the robot selection problem of a new pharmaceutical city in Egypt. The research demonstrates that, compared to conventional and fuzzy ordinal priority techniques, the suggested approach for robot selection is very beneficial and performs very well under uncertainty. The suggested method also takes up less time and is easier to use than the fuzzy ordinal priority method. Quartey-Papafio et al. (2021) used the OPA to select suppliers for the health sector based on the responses of three employees from a private health agency's procurement team on four criteria: quality of products, pricing, delivery performance, and standard of service. Islam (2021) initiates a new approach to assessing low-carbon and sustainable farming technologies using three separate sustainability criteria. He does this by using the OPA-Grey. Data were gathered for that through a planned survey in which ten decision-makers were randomly selected from ten different countries and fields. The research revealed that integrated crop-livestock systems are the optimal strategy for increasing food production and promoting sustainable development while also enhancing environmental

quality by lowering net GHG emissions. Candra (2022) uses the OPA-Grey to identify the variables influencing electric vehicle adoption in Indonesia and assesses the obstacles to their widespread adoption in the nation. The primary barriers to their adoption have been identified as high initial purchase costs, a lack of infrastructure investment, and a lack of government incentives. Pamucar et al. (2022a) created a novel extension of the OPA under picture fuzzy sets to prioritize freight company transportation planning methods. To do so, four alternatives are taken into account and assessed using the fourteen criteria listed under the categories of transportation, organizational, economic, and environmental. According to the results of their analysis, the most crucial factors that significantly influence the ranking of alternatives are rising fuel costs, optimum network capacity use, and carbon footprint mitigation. While integrating many transportation modes is thought to be a sustainable choice, unimodality is chosen as the most advantageous option. Pamucar et al. (2022a) developed a new Rough Aczel-Alsa function and the OPA to offer a scenario integrating three metaverse implementation options in transportation systems. These alternatives are prioritized based on thirteen sub-criteria organized into four major categories. A novel hybrid model based on q-rung orthopair fuzzy sets was developed by Deveci et al. (2022) to examine three potential implementation strategies for autonomous vehicles in the metaverse. Twelve different criteria, categorized into four primary categories: technological, sociological, legal and ethical, and transportation, are used to evaluate these possibilities. The findings indicate that the best choice among the three possibilities is autonomous vehicles in the metaverse are controlled by the same central system. Le and Nhieu (2022) provide an integrated OPA and fuzzy evaluation based on distance from average solution to investigate the post-COVID-19 production strategies in the Vietnamese manufacturing sector. The findings show that digitization and on-site renewable energy are the most crucial industrial recovery solutions. OPA and Technique for Order Preference by Similarity to Ideal Solution methodologies were used by Bah and Tulkinov (2022) to assess Chinese suppliers of automotive components using resilience criteria. However, there is no existing study until now that applied the OPA approach in the road sector, especially the factors affecting its maintenance. To handle this knowledge gap, the current study focuses on classifying the counties in order of critical severity based on factors affecting road maintenance in Kenya using the OPA in multiple attribute decision-making (MADM). To reach the goal of this study, subsequent research questions (Q) were formulated:

Q1: What are the factors influencing road maintenance in the context of Kenya?
Q2: Which are the most critical factors affecting road maintenance?
Q3: What are the top counties that have been affected by these critical influential factors?

As a result, we examined factors based on previous studies. To evaluate the relevance of factors in the road maintenance environment, we gathered decision-makers' points of view in the road sector. In addition, the OPA methodology is used in this study, which is a relatively new method in the MADM setting. The current study will offer appropriate actions based on the innovations described, which will either be established or may identify the most crucial issues that affect the effectiveness of handling road maintenance in these selected counties.

The remainder of this study is divided into the sections listed below. Section 2 describes the OPA and related calculating processes. Section 3 discusses the study's methodology based on the data gathering approach, obtained data, and the framework for evaluating county-based factors affecting road maintenance. Section 4 displays the results and discussion. The final section contains the conclusion and recommendations.

2. Ordinal Priority Approach

Ataei et al. (2020) recently advocated the OPA, which is based on ordinal relations and linear programming, to address the problem of the restricted number of specified scales in conventional methodologies for evaluating criteria (Badi & Abdulshahed, 2019; Bakır & Atalık, 2021; Bouraima et al., 2021; Stevic et al., 2017; Stevic et al., 2022). The distinguishing features of this approach were that it did not require the normalization procedure, pairwise comparisons, or information perfectness Pamucar et al. (2022b).

The OPA is used in this study to analyze the weights of the decision-makers and criteria, as well as classify the counties based on the factors impacting their maintenance. This section summarized the OPA's computation steps. Table 2 shows the method's fundamental parameters. The pertinent steps of the OPA are described here, based on the later research of Ataei et al. (2020) and Quartey-Papafio et al. (2021).

Step 1: Examining the affecting factors of the road maintenance for county classification
Step 2: Definition of the ordinal preference of affecting 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 adequate software such as EXCEL in our case.

Max Z
S.t:

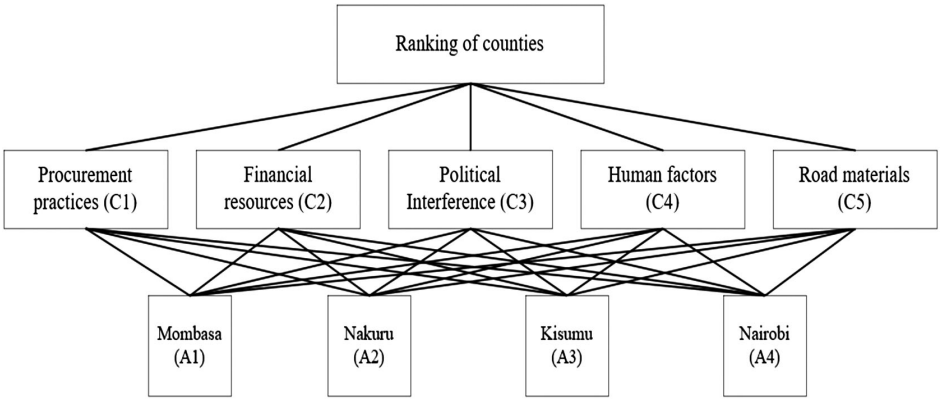
$$\begin{aligned} & Z \le i\left(j\left(k\left(W_{ijk}{}^{r} - W_{ijk}{}^{r+1}\right)\right)\right) && \forall\, i,j \text{ and } k \\ & Z \le \ ijmW_{ijk}{}^{m} && \forall\, i,j \text{ and } k \\ & \sum_{i=1}^{p}\sum_{j=1}^{n}\sum_{k=1}^{m} W_{ijk} = 1 \\ & W_{ijk} \ge 0 && \forall\, i,j \text{ and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

where Z: Limitless in sign

Table 2
OPA categories, indicators, and determinants

Categories	
I	Category of decision-makers $\forall I \in$ I
J	Category of criteria $\forall j \in$ J
K	Category of alternatives $\forall k \in$ K
Indicators	
i	Indicator of the decision-makers $(1,\ldots,p)$
j	Indicator of preference of the criteria $(1,\ldots,n)$
k	Indicator of the alternatives $(1,\ldots,m)$
Determinants	
Z	Key function
$W_{ijk}{}^{k}$	Significance (value) of k^{th} alternative by i^{th} decision-maker at k^{th} ranking according to j^{th} criterion
Parameters	
i	The classification of decision-maker i
j	The classification of criterion j
r	The classification of alternative k

Figure 1
The ranking of four counties based on factors influencing their road maintenance



Following the resolution of the model, Equations (2)–(4) are used to determine the weights of the alternatives, criterion, and decision-maker(s). In the current investigation, Equation (2) should be applied to calculate the weights of alternatives, which are counties.

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

Equation (3) should be used to obtain the weights of the criteria.

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

Equation (4) should be applied for the determination of the weights of decision-makers.

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

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

3. Methodology

The data were gathered from three distinct experts using the hierarchical framework shown in Figure 1. Out of 47 counties in Kenya, four counties were chosen: Mombasa (A1), Nakuru (A2), Kisumu (A3), and Nairobi (A4) based on the density of their road networks and the degree of maintenance performed annually. These counties were evaluated using the influential criteria that respondents were aware of. The respondents worked for the Kenya National Highways Authority, the Kenya Urban Roads Authority, and at university, in that order. Decisions were made based on five criteria: procurement practices (C1), financial resources (C2), political involvement (C3), human factors (C4), and road materials (C5). All of the criteria are positive, except financial resources (C2), which is a negative criterion. These five criteria were chosen based on previous research (Luka, 2016; Sindiga et al., 2019; Wambugu, 2017), as well as expert confirmation. The data collection is displayed in Tables 3 and 4. The numbers 1, 2, 3, 4, and 5 in these tables correspond to the first, second, third, fourth, and fifth choices, respectively. Using the OPA, the counties will be ranked. Utilizing the model has the advantage of preventing data normalization, for example, one can ignore which criteria were higher-the-greater and which were lower-the-greater because the components are evaluated according to their individual choices.

Table 3
Criteria's relative weights

	C1	C2	C3	C4	C5
E1	2	3	4	1	5
E2	2	2	3	1	3
E3	1	1	2	3	3

4. Results and Discussion

In this part, the weights of the model's three elements were calculated using Equations (2)–(4). They were then ranked in the descending order, with lesser weight indicating lower rank. Table 5 shows the weighting and ranking of the OPA's three components.

The procurement processes, with a value of 0.289, are the most important factor affecting road maintenance, as shown in Table 5.

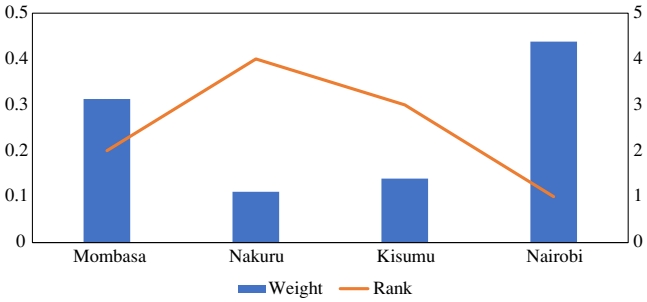
Table 4
Alternative significance concerning each criterion

		A1	A2	A3	A4
E1	C1	1	4	2	3
	C2	1	2	4	3
	C3	1	4	2	3
	C4	1	2	3	4
	C5	4	2	3	1
E2	C1	2	4	3	1
	C2	1	3	2	1
	C3	1	3	2	1
	C4	2	4	3	1
	C5	2	3	4	1
E3	C1	2	3	4	1
	C2	2	4	3	1
	C3	4	2	3	1
	C4	2	3	4	1
	C5	2	4	3	1

Table 5
The weighting and ranking of the OPA's three components

		Weight	Rank
Decision-makers	E1	0.146798	3
	E2	0.547816	1
	E3	0.305384	2
Criteria	C1	0.289311	1
	C2	0.225020	3
	C3	0.234395	2
	C4	0.141977	4
	C5	0.109295	5
Alternatives	A1	0.312661	2
	A2	0.110411	4
	A3	0.139164	3
	A4	0.437762	1

Figure 2
Classification of counties



Our findings are consistent with other studies by Luka (2016) and Sindiga et al. (2019), which conclude that the procurement practice and the construction project's effectiveness are inextricably linked. According to their weight calculation results, the following two components, namely political influence and financial resources, are rather close. The road materials remain the least influential component. When the alternatives are considered, Nairobi County (A4) emerges as the top county, followed by Mombasa (A1), Kisumu (A3), and then Nakuru (A2), as shown in Figure 2. As a result, A4 is more influenced by elements during road maintenance than in other counties. Simultaneously, Nakuru (A2) has been less affected. It should be noted that many counties performed differently. This is owing to differences in the size and categorization of their road networks, as well as the number of projects (new construction and rehabilitation) that each county is now doing.

5. Conclusion and Recommendations

In this study, the OPA is utilized to prioritize Kenyan counties based on factors affecting their road maintenance. As a result of the literature review, five criteria (influential elements) were used: procurement practices, financial resources, political interference, human factors, and road materials. The survey includes the opinions of three decision-makers. The study's findings revealed that procurement practices are the most important factors affecting road maintenance effectiveness, followed by political interference and financial resources. The least important factor impacting the effectiveness of road maintenance remains the road materials.

Given the negative effects of these influencing variables on road maintenance, it is first advised that institutions adopt, authorize, and implement practices and regulations concerning management records that include responsibilities in procurement offices. In addition, within each road agency, a specific unit should be established to handle and control all issues involving political interference so that services can be offered to the public without prejudice. Finally, adequate financial resources should be available to build more roads and maintain existing ones so that growth in all counties can be accelerated.

This is the first study of its sort in Kenya, incorporating the use of an OPA to assess the most important elements influencing the performance of road maintenance and to rank counties based on these key aspects. The applied technique illustrated how the criteria were examined without the need of a decision-making matrix or a pairwise comparison matrix, as well as the ability of the decision-makers to only appraise alternatives and attributes for which they have sufficient information and competence. As a result, the method outlined here has the potential to be used in a wide range of situations.

The approach's most serious flaw is that it does not account for scenarios in which decision-makers have questions about their judgment. Because of the more dynamic environmental conditions, as well as 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 under fuzzy and grey environments. Another flaw in this article is that just five criteria were evaluated, as well as the opinions of only three decision-makers. Future research may take into account other characteristics such as project team capacity, managerial assistance, monitoring, and assessment. Furthermore, the number of professionals with diverse backgrounds should increase.

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Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

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