An Integrated Decision Support Model for effective Institutional Coordination Framework in Public Transportation Planning

Mouhamed Bayane Bouraima (mouba121286@yahoo.fr)
Southwest Jiaotong University School of Civil Engineering https://orcid.org/0000-0002-5801-884X
Janet Oyaro
Masinde Muliro University of Science and Technology
Ertugrul Ayyildiz
Karadeniz Technical University: Karadeniz Teknik Universitesi
Melike Erdogan
Duzce University: Duzce Universitesi
Kevin Maraka Ndiema
University of Eldoret

Research Article

Keywords: Interval-valued spherical fuzzy numbers, institutional coordination, planning, public transportation, SWARA, TOPSIS

Posted Date: February 10th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-2548803/v1

An Integrated Decision Support Model for effective Institutional Coordination Framework in Public Transportation Planning

Abstract

The lack of coordination among global institutions responsible for planning public transportation is a persistent issue. To tackle this issue, three strategies aimed at promoting sustainability have been proposed. However, there is a significant deficiency in preferentially prioritizing them, which poses a significant issue for local governments. In this study, a two-stage model is established by combining the Step-wise Weight Assessment Ratio Analysis and the Technique for Order of Preference by Similarity to Ideal Solution methods into a unique interval-valued spherical fuzzy framework. This allows for determining the criteria weights and ranking the strategies. The results of our investigation show that effective institutional coordination in public transportation planning can be achieved through the implementation of good governance principles. By doing so, Nairobi's local government can tackle the unexpected division of public transportation agreements among different institutions and guide the various sectors in executing their transportation plans while still adhering to the established policy objectives.

Keywords: Interval-valued spherical fuzzy numbers; institutional coordination; planning; public transportation; SWARA; TOPSIS.

1. Introduction

The coordination of public transportation is vital for increasing mobility and ensuring easy access to essential services. In many cities, cooperation between the institutions responsible for planning public transportation is critical, as it is often provided by a variety of public and private entities (Hatzopoulou & Miller, 2008). To avoid conflicting internal operations, it is necessary to resolve the interconnected challenges within the public transportation sector, which involve multiple institutional commitments, differing perceptions, and varied interpretations of cause and effect (Stewart, 2005).

The coordination of public transportation planning differs between countries because of the cultural differences and levels of authority among government bodies (Banister, 2005). This issue takes on different forms based on the level of the country's development. In East Africa, poor coordination leads to inadequate transportation planning and unreliable public transportation services in urban areas. An example of this is seen in Nairobi, Kenya, where the rapid population growth and lack of effective transportation services led to worsening issues in the 1970s, such as traffic congestion, poor customer service, increased accidents, air pollution, and delays in reaching destinations (Asingo, 2004; Obudho, 1997). Despite the government's authorization of private sector involvement, the quality of transportation services remained substandard.

As the public became increasingly frustrated with transportation problems, more individuals and groups invested in finding solutions. Despite various efforts, such as updating Nairobi's development plans and changing regulations for bus services, progress in improving public transportation was slow to materialize (Kanyama & Cars, 2009). These challenges are reflective of the broader trend in sub-Saharan Africa, where urban areas are growing at a faster rate than in other regions (El-Shakhs, 1997).

Nairobi's local government is facing a growing challenge of coordinating different institutions in the city's public transportation planning. A framework for institutional coordination in public transportation planning was proposed but was not effective in addressing these issues because no appropriate strategy was adopted. Finding the appropriate strategy to resolve these issues in public transportation planning and achieve effective coordination is a complicated task that demands the expertise of a multidisciplinary team. Multi-Criteria Decision Making (MCDM) is an effective and adaptable approach for tackling public transportation planning issues (Alkharabsheh et al., 2022; Bouraima et al., 2022; Bouraima et al., 2020; Bouraima et al., 2021; Bouraima et al., 2023). The decision-making procedure often presents challenges to experts due to incomplete information and uncertainty. Available research has yet to fully address these difficulties.

1.1. Objectives

This research delves into a specific issue with implementing proper coordination among institutions in public transportation planning in Nairobi and offers solutions from an MCDM perspective. Three strategies are evaluated using seven criteria related to coordination challenges. These strategies aim to address problems such as the fragmentation of transportation agreements and guide different sectors in aligning their transportation plans with overall policy objectives. The study also provides a methodology that could be implemented in related transportation planning issues and presents a plan for selecting the most appropriate strategy for institutional coordination using Nairobi as an example.

1.2. Motivation

Since the establishment of fuzzy sets (FSs), they have got exceptional attention and have been applied in several aspects of science. Kutlu Gündoğdu and Kahraman (2019) generalized the intuitionistic fuzzy sets (IFSs) by introducing the spherical fuzzy sets (SFSs). SFSs lessen information loss and detorsion by allowing decision-makers (DMs) to express their doubt about certain parameters. Additionally, by modeling issues without a single point, DMs can use interval-valued fuzzy sets (IVFSs) to specify their decisions (Gul & Yucesan, 2021). Given all these benefits, applying the interval-valued spherical fuzzy sets (IVSFSs) to linguistic assessments represents one of the most rational methods for dealing with uncertainty. Although a greater area is required in the SFSs to freely allocate membership variables, the application of interval-valued theory with these sets enhances the capacity for dealing with uncertainty (Zhou et al., 2021). IVSFSs eliminate certain discrepancies in the previous fuzzy sets and take into account impartial hesitation (Gul & Ak, 2021). IVSFSs are preferred because they allow for greater inclusion of uncertainty in the variables of an FS with an interval as opposed to a single point (Farrokhizadeh et al., 2021). Due to all of these factors, IVSFSs are used to model all uncertainty and best incorporate DM assessments into the decision-making procedure.

Keršuliene et al. (2010) introduced the Step-wise Weight Assessment Ratio Analysis (SWARA) method for criteria weight determination. Its calculation process is simple and clear (Ayyildiz, 2022; Tanackov et al., 2022; Bouraima et al., 2022). The key component of this method is the capacity to gauge the evaluation of experts based on the significance ratio of the variables. Because of these, the method is used for criteria determination in the IVSF environment.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method developed in 1981, is a relatively simple method (Hwang and Yoon, 1981). It has a significant benefit because it can quickly identify the appropriate option (Akram et al., 2019; Deveci et al., 2018; Garg & Kumar, 2020). Kim et al. (1997) identified four benefits of TOPSIS: (1) a scalar value that instantaneously stands for the perfect and the worst options; (2) a sound rationale that reflects the basis of people's thought; (3) the ability to visualize the performance indicators of all options on a polyhedron, at least in two dimensions; and (4) an easy-to-implement calculation procedure that can be coded into a worksheet. Because of these, IVSF-TOPSIS is used to assess and rank the strategies.

1.3. Structure of the study

After the initial introduction, an overview of prior research is presented, followed by an explanation of the criteria and alternatives under consideration. This is followed by a description of the methodology, which is then demonstrated through a real-life case study. The sensitivity analysis is then explained, followed by a discussion of the results and their impact on policy. The final section consists of conclusions and suggestions for further study.

2. Literature review

Six sub-sections are presented herein below.

2.1. Abbreviations

The abbreviations are provided in **Table 1.**

Table 1. Abbreviations

AHP	Analytic Hierarchy Process	**IVTFN**	Interval-valued Triangular Fuzzy Number
Alt.	Alternative	**IVN**	Interval-Valued Number
ARAS	Additive Ratio Assessment	**MABAC**	Multi-Attributive Border Approximation area Comparison
BWM	Best Worst Method	**MARCOS**	Measurement of Alternatives and Ranking according to COmpromise Solution
CIFS	Complex Intuitionistic Fuzzy Soft	**MC**	Main Criteria
CoCoSo	Combined Compromise Solution	**MEREC**	Method based on the Removal Effects of Criteria
COPRAS	Complex Proportional Assessment	**N**	Neutrosophic
CRITIC	CRiteria Importance Through Intercriteria Correlation	**PF**	Pythagorean Fuzzy
DEA	Data Envelopment Analysis	**PFS**	Pythagorean Fuzzy Set
EDAS	Evaluation based on Distance from Average Solution	**PROMOTHEE**	Preference Ranking Organization Method for Enrichment Evaluation
F	Fuzzy	**QFD**	Quality Function Deployment
FR	Fuzzy rough	**qROFS**	q-rung orthopair fuzzy set
GDM	Group Decision Making	**RL**	Real-life
GRA	Grey relational analysis	**SA**	Sensitivity analysis
IE	Illustrative Example	**SERVQUAL**	Service Quality
IF	Intuitionistic Fuzzy	**TF**	Triangular Fuzzy
IMF SWARA	Improved Fuzzy Step-wise Weight Assessment Ratio Analysis	**T2NN**	Type-2 Neutrosophic Number
IT2F	Interval Type-2 Fuzzy	**WASPAS**	Weighted Aggregated Sum Product Assessment
IVFF	Interval-Valued Fermetean Fuzzy		
IVIF	Interval-Valued Intuitionistic Fuzzy		

2.2. Decision-making procedures related to planning for public transportation

Several studies have been conducted on the institutional challenges impacting the planning, execution, and maintenance of transportation systems. Stough and Rietveld (1997) looked at the institutional issues affecting transportation. The effectiveness of transportation systems and identified key elements that could aid in the development of metropolitan transportation are investigated (Sampaio et al., 2008). Blumenberg (2002) examined how well local transportation and welfare-to-work initiatives reflected the five factors that influence local intersectoral interactions. Abd Rahman and Abdullah (2016) examined the institutional framework on a large scale to resolve the major issues with urban transportation. Kanyama (2016) investigated the barriers to institutional coordination in public transportation planning. Kanyama et al. (2006) examined the methods and configurations of stakeholder engagement and participation in public transportation planning. The ineffectiveness of public transportation from the perspectives of urban development and institutional responsibility has been the main focus of Kanyama et al. (2005). Hatzopoulou and Miller (2008) evaluated the degree of institutional integration in transportation-related policy evaluation, financing, and implementation. An overview of approaches in public transportation planning is shown in **Table 2**.

Table 2. Overview of approaches related to public transportation planning

Author (s)	**Empirical focus**	**GDM**	**SA**	**Method (s)**	**Application**	
					Country/Region	**Type**
Stough and Rietveld (1997)	Institutional problems impact assessment	No	No	Qualitative study	Europe, United States	RL
Sampaio et al. (2008)	Efficiency analysis	No	No	DEA	Europe, Brazil	RL
Blumenberg (2002)	Collaborative planning for transportation needs	No	No	Survey-based method	California	RL
Abd Rahman and Abdullah (2016)	Urban transport management approach	No	No	Qualitative analysis	Malaysia	RL
Kanyama (2016)	Institutional coordination framework in planning	No	No	Structural-functional analysis, content analysis	Nairobi (Kenya)	RL
Kanyama et al. (2006)	Public participation and institutional coordination framework in planning	Yes	No	Focus group interview	Dar-es-Salaam (Tanzania)	RL
Kanyama et al. (2005)	Institutional coordinatization perspective analysis	Yes	No	Literature review, official documents, and interviews	Dar-es-Salaam (Tanzania)	RL
Hatzopoulou and Miller (2008)	Institutional integration assessment	No	No	Survey-based method	Canada	RL
Our study	Address the issues of the effective implementation of adequate institutional coordination in public transportation planning based on appropriate strategy selection	**Yes**	**Yes**	**SWARA, TOPSIS**	**Nairobi, Kenya**	RL

2.3. Applications of MCDM approach on public transportation

Multi-criteria approaches have been applied in several aspects of public transportation, including sustainability, optimization, prioritization, and management (Gokasar, Timurogullari, Deveci, et al., 2022; Gokasar, et al., 2022; Pamucar et al., 2020; Pamucar et al., 2022). Deveci (2022) classified the sustainability of transportation in virtual worlds. The operation of urban transportation through the epidemic has been evaluated and prioritized (Deveci et al., 2022). Simic, et al. (2022) addressed the issue of choosing a costing system under public transportation. Pamucar et al. (2021) prioritized the benefits of electric ferries under a durable supply chain. Simic et al. (2022) examined the selection of sustainable policies to minimize the influence of transportation on the modification of climate. Erdoğan and Kaya (2020) proposed a tool to decrease the risks associated with bus rapid transit system failures. Bilişik et al. (2013) evaluated the quality of the transportation services. Erdoğan and Kaya (2016) chose the most suitable alternative fuel bus for public transportation. Görçün (2021) selected the railway vehicles that should be utilized for public transportation. Nassereddine and Eskandari (2017) studied the issue of passenger satisfaction levels with public transportation. Hajduk (2021) examined the choice of smart cities based on urban transportation. Celik et al. (2013) determined and enhanced the satisfaction of the customer. Celik et al. (2016) evaluated the efficacity of public transportation systems. **Table 3** indicates the multi-criteria approaches in public transportation.

Table 3. A multi-criteria approach for public transportation.

Authors	Research focus	GDM	Parameter type	SA	Methods	Application		MC	Alt.
						Country/region	Type		
Deveci (2022)	Urban transportation assessment in the metaverse	Yes	q-ROFS	Yes	MEREC, SWARA	-	RL	3	3
Deveci et al. (2022)	Public transport management	Yes	Fuzzy	Yes	CoCoSo	-	RL	3	4
Simic, Gokasar, Deveci and Karakurt (2022)	Cost system choice	Yes	T2NN	Yes	CRITIC, MABAC	Turkey	RL	4	4
Pamucar et al. (2021)	Sustainable supply chain management	Yes	Fuzzy	Yes	WASPAS	Istanbul, Turkey	RL	4	4
Simic, Gokasar, Deveci and Švadlenka (2022)	Urban transport impact on climate change	Yes	T2NN	Yes	MEREC, MARCOS	-	RL	4	4
Erdoğan and Kaya (2020)	Risk and failure assessment	Yes	Fuzzy, stochastic, heuristic	Yes	Methodical technique based on maintenance decision-making tool	Istanbul, Turkey	RL	-	5
Bilişik et al. (2013)	Customer satisfaction assessment	Yes	Fuzzy	Yes	Delphi method, SERVQUAL, AHP, TOPSIS	Istanbul, Turkey	RL	5	4

Erdoğan and Kaya (2016)	Alternative fuel bus selection	Yes	T2F	No	Delphi method, AHP, TOPSIS	Istanbul, Turkey	RL	5	4
Görçün (2021)	Urban railway vehicle selection	Yes	Crisp	No	CRITIC, EDAS	Turkey	IE	-	10
Nassereddine and Eskandari (2017)	Public transportation system evaluation	Yes	Crisp	Yes	GAHP, PROMETHEE	Tehran, Iran	RL	6	5
Hajduk (2021)	Smart city selection	No	Crisp	Yes	Entropy weight, TOPSIS	-	RL	7	44
Celik et al. (2013)	Customer satisfaction assessment	Yes	IT2F	Yes	TOPSIS, GRA	Istanbul, Turkey	RL	8	4
Celik et al. (2016)	Service quality evaluation	Yes	IF	No	TOPSIS	Istanbul, Turkey	RL	-	7
Our study	**Institutional coordination evaluation in planning for public transportation**	**Yes**	**IVSF**	**Yes**	**SWARA, TOPSIS**	**Nairobi, Kenya**	**RL**	**7**	**3**

2.4. SWARA method

Several studies have effectively addressed a range of decision-making problems using the method developed by Keršuliene et al. (2010). Mohammadian et al. (2021) evaluated the implementation of the internet of things in agriculture. Garg et al. (2022) addressed the software choice issues. Mishra et al. (2020) chose the most appropriate bioenergy production technology. Pajić et al. (2021) assessed and selected the key parameters in logistics. Baç (2020) recommended an assessment framework for smart card systems. Zolfani and Chatterjee (2019) compared the sustainability of different household materials. Xiang et al. (2022) ranked coal transportation enterprises based on competitiveness and cost. Stević et al. (2022) evaluated information technologies for warehouse order selection. Vrtagić et al. (2021) ranked road sections based on safety. Matić et al. (2022) evaluated the performance of construction equipment to improve road infrastructure. **Table 4** indicated the survey related to this method.

Table 4. Survey of the SWARA method

Authors	**Research focus**	**GDM**	**Environment**	**Method(s)**	**Appl.**	**MC**	**Alt.**
Keršuliene et al. (2010)	Choice of logical disagreement resolution	Yes	Crisp	SWARA	RL	6	-
Mohammadian et al. (2021)	Applications of the internet of things in the agriculture sector	Yes	IVTFN	SWARA, ARAS	RL	22	8
Garg et al. (2022)	Software selection	Yes	CIFS	SWARA, COPRAS	IE	7	4
Mishra et al. (2020)	Bioenergy production procedure assessment	Yes	IF	SWARA, COPRAS	RL	11	6
Pajić et al. (2021)	Performance of procurement and distribution logistics	Yes	Crisp	SWARA, QFD	RL	15	-

Baç (2020)	Smart card systems assessment	Yes	Crisp	SWARA, WASPAS	RL	10	4
Zolfani and Chatterjee (2019)	Sustainable material selection	Yes	Crisp	SWARA, BWM	RL	17	-
Xiang et al. (2022)	Choice of coal transportation enterprise	Yes	TF	SWARA, COPRAS	RL	4	5
Stević et al. (2022)	Information technology assessment	Yes	Z number	IMF SWARA, EDAS	RL	4	4
Vrtagić et al. (2021)	Classification of the road section	Yes	Fuzzy	DEA, IMF SWARA, MARCOS	RL	8	6
Matić et al. (2022)	Choice of construction machinery	Yes	FR, D number	IMF SWARA, MARCOS	RL	16	12
Our study	**Institutional coordination evaluation in planning for public transportation**	**Yes**	**IVSF**	**SWARA, TOPSIS**	**RL**	**7**	**3**

2.5. TOPSIS method

This method has been used in a variety of studies to determine the best course of action. For example, Abdul and Wenqi (2022) selected the most appropriate communication technology for the smart grid. Bilgili et al. (2022) determined the most suitable options for renewable energy. Saeidi et al. (2022) identified the most critical parameters in sustainable personnel management. Ayyildiz and Taskin Gumus (2021) evaluated the factors that affect student ergonomics. The maintenance of bridge projects has been prioritized through the emissions of carbon dioxide (Gokasar et al., 2021). Reig-Mullor et al. (2022) evaluated the sustainable corporate performance of companies. Ilieva and Yankova (2022) assessed COVID-19 vaccines based on their clinical features and effectiveness. Kahraman et al. (2022) assessed the sustainability of third-party logistics companies. Zhang et al. (2022) assessed the risk associated with the subway station. Yildiz et al. (2022) assessed the reliable route for cash-in-transit activities. Gulum et al. (2021) investigated the fire risk after an earthquake. The survey related to this method is presented bellows (**Table 5**).

Table 5. Survey of TOPSIS method

Authors	**Research focus**	**GDM**	**Env.**	**Method(s)**	**Appl.**	**MC**	**Alt.**
Abdul and Wenqi (2022)	Communication technology for smart grid evaluation	Yes	F	TOPSIS	RL	9	2
Bilgili et al. (2022)	Renewable energy alternative assessment	Yes	IF	TOPSIS	RL	25	4
Saeidi et al. (2022)	Sustainable personnel management assessment	Yes	PFS	SWARA, TOPSIS	RL	20	3
Ayyildiz and Taskin Gumus (2021)	Ergonomics listing and risk assessment of pandemic	Yes	PF	AHP, TOPSIS	RL	39	100
Gokasar et al. (2021)	Bridge projects evaluation	Yes	T2NN	WASPAS, TOPSIS	RL	8	5

Reig-Mullor et al. (2022)	Sustainability performance of oil and gas companies	Yes	N	AHP, TOPSIS	RL	10	8
Ilieva and Yankova (2022)	Vaccines assessment	Yes	IVFF	TOPSIS	RL	5	15
Kahraman et al. (2022)	Performance assessment of 3PL enterprises	Yes	IVIF	TOPSIS	RL	5	8
Zhang et al. (2022)	Operational risk assessment of subway station	Yes	IT2F	TOPSIS	IE	22	2
Yildiz et al. (2022)	Cash transit operation assessment	Yes	IVIF	AHP, TOPSIS	RL	24	4
Gulum et al. (2021)	Post-earthquake fire risk evaluation	Yes	IVN	AHP, TOPSIS	RL	19	14
Our study	**Institutional coordination evaluation in planning for public transportation**	**Yes**	**IVSF**	**SWARA, TOPSIS**	**RL**	**7**	**3**

2.6. Research gaps and contributions

This study addressed a specific local issue in Nairobi related to effective institutional coordination in public transportation planning. The study is unique in that it chooses the most appropriate strategy to address these challenges, which have not been previously investigated and prioritized (see **Table 1**). Additionally, the study combines the use of the SWARA and TOPSIS approaches for public transportation planning, which has not been done before (see **Tables 3 and 4**). Furthermore, the study utilizes these methods to identify and classify challenges and suggest practical solutions to overcome them in the context of institutional coordination in public transportation planning, which has not been previously explored (See **Tables 1, 2, 3, and 4**).

This study differentiates itself from other methods by using the IVSFS approach, which has proven to be more beneficial when dealing with ambiguity in expert opinions in real life. It proposes a comprehensive framework for decision-making by combining the TOPSIS and SWARA methods in an IVSF setting. The study has two stages, it first used IVSF-SWARA for weighting criteria, and then used IVSF-TOPSIS for evaluating and ranking strategies for successful institutional coordination in public transportation planning. This proposed framework can aid policymakers in effectively addressing the challenges in institutional coordination and selecting the most appropriate strategy for real life.

Although this research specifically focuses on identifying the most appropriate strategy for successful institutional coordination in public transportation planning in Nairobi, however, the methodology herein can be implemented in other similar decision-making problems. Additionally, this is the first time that this issue has been examined from an MCDM perspective in the context of Nairobi, making it a unique contribution to the field. Furthermore, the study establishes seven key criteria for decision-making, providing a practical framework for assessing the most appropriate strategy for institutional coordination in public transportation planning. The research concludes with specific recommendations for Nairobi, making it a useful guide for real life.

3. Problem definition

The effectiveness of institutional coordination in public transportation planning in Nairobi has become a pressing issue that requires attention and resolution. To address this issue, various strategies have been proposed to improve coordination efforts. It is essential that experts carefully consider and weigh different options to establish a strong institutional coordination framework for the advancement of public transportation planning in the city.

3.1. Alternatives

Three alternatives have been recommended based on previous studies and viewpoints of experts as follows:

S1: *Strategic planning and implementation*: Governments should approach infrastructure planning in a strategic manner (ALCHIN et al., 2021). A detailed, comprehensive, and regularly updated strategic infrastructure plan should be used to convey this approach. The plan should be linked to clear and specific infrastructure funding packages, and a project pipeline should be outlined at a minimum. Governments should consider the benefits of establishing independent infrastructure consulting organizations to provide expert guidance on the implementation of long-term, cross-sector infrastructure strategy, planning, and policy, as well as the top priorities for mid to long-term infrastructure investments.

S2: *Good governance*: The management and regulation of public transportation are governed by several rules and procedures known as governance. A suitable legal framework and the appropriate distribution of roles, responsibilities, and authority are crucial elements of an efficient governance model for urban public transportation (Hirschhorn et al., 2020).

S3: *Good leadership principles or Ethical leadership*: Ethical Leadership requires promoting the actions of others and resolving conflicts by prioritizing principles such as accountability, fairness, trustworthiness, respect, justice, and honesty, which are considered key elements of successful leadership. Therefore, local authorities should have leaders who plan for public transportation with strong moral principles (Buye, 2020). In general, improving coordination among institutions in planning public transportation requires ethical leadership which is connected to effective leadership and good governance (Kanyama, 2016).

3.2. Criteria

Seven criteria have been recommended based on previous studies and viewpoints of experts as follows:

C1: *Poor vision/plan of the city*: The physical plans of Nairobi have remained largely unchanged despite changes in urbanization. The initial plan of Nairobi dating back to 1948, reflected the colony's racial and commercial segregation policies (Obudho, 1997). Even today, Nairobi still displays these separate and unequal lifestyles and zoning practices (Kanyama, 2016).

C2: *Poverty*: The weak economy of Kenya, like that of other sub-Saharan countries, has limited the ability of cities to deal with forces driving urban development (Okpala, 2009). It is difficult to have good public transportation based on effective institutional coordination because poverty in Kenya continues to impede land use and public transportation strategies, prevent people from paying for their travel expenses or prevent operators from making money to support the transportation sector.

C3: *Fear of change*: The coordination of plans for public transportation is hindered by the concern that the modification of current systems might create new issues that would be difficult to address. Many small buses are currently used in public transportation systems, which are thought to employ a large number of people (Kane, 2002). The potential to modernize these systems could attract new drivers whose preference, will result in a decrease in employment in the sector.

C4: *Lack of political will/corruption*: The transportation in Nairobi is susceptible to the application of unconnected projects with the potential for bribes and opportunities for property speculation for leaders (Klopp, 2012). Decisions are often based on “planning”, which promotes the idea of territorial and social separation, exacerbating inequality (Linehan, 2007).

C5: *Lack of regulatory framework*: The lack of institutional and legal foundations necessary for the city development, due to governments' unwillingness to establish them, has resulted in obstructive legal standards, dishonest public officials, and a highly prevalent informality (Tostensen et al., 2001). Many officials faced crisis management, which involves limited rational decisions, outdated plans, and decisions made without consultation.

C6: *Inadequate fiscal decentralization*: A significant drawback in African cities is the insufficient fiscal and political decentralization, frequently caused by ministries' reluctance to relinquish their responsibilities out of fear of losing control over projects, money, and power (Smoke, 2003). Central governments tend to give local ones the most autonomy possible without allocating additional funds (Wekwete, 1997). They monitor the wealthiest and most thriving taxes but did not consider the establishment of well-planned financing systems at the local level and are also hesitant to allow municipal authorities to legally create their sources of income (Rakodi, 2016).

C7: *Inadequate participation in planning*: The colonial-era approach to urban planning and management is responsible for the widespread lack of participation in planning among institutions in the region, as stated by Wekwete (1997). Despite an increase in the participation of various parties in the management of African urban sectors, the traditional method of management remains dominated by public sector investment. Under this approach, the local and central governments provide social services with minimal input from non-governmental organizations and private industry.

4. Adopted Methodology

The methodology to handle the problem in this paper is introduced in the following sub-sections.

4.1. IVSFSs

The definitions and the basic arithmetic operations of IVSFS are presented (Gündoğdu & Kahraman, 2019).

Definition 4.1: Equation (1) described an IVSFS $\tilde{A}_S$ of the nature of discussion U.

$$\tilde{A}_S = \{\langle u, ([\mu^L_{\tilde{A}_S}(u), \mu^U_{\tilde{A}_S}(u)], [v^L_{\tilde{A}_S}(u), v^U_{\tilde{A}_S}(u)], [\pi^L_{\tilde{A}_S}(u), \pi^U_{\tilde{A}_S}(u)]) | u \in U\} \quad (1)$$

where $0 \le \mu^L_{\tilde{A}_S}(u) \le \mu^U_{\tilde{A}_S}(u) \le 1, 0 \le v^L_{\tilde{A}_S}(u) \le v^U_{\tilde{A}_S}(u) \le 1$ and $0 \le \left(\mu^U_{\tilde{A}_S}(u)\right)^2 + \left(v^U_{\tilde{A}_S}(u)\right)^2 + \left(\pi^U_{\tilde{A}_S}(u)\right)^2 \le 1$.

For every $u \in U, \mu^U_{\tilde{A}_S}(u), v^U_{\tilde{A}_S}(u)$ and $\pi^U_{\tilde{A}_S}(u)$ are superior levels of membership, non-membership, and hesitancy of u to$\tilde{A}_S$, respectively. For every $u \in U$, if $\mu^L_{\tilde{A}_S}(u) = \mu^U_{\tilde{A}_S}(u), v^L_{\tilde{A}_S}(u) = v^U_{\tilde{A}_S}(u)$ and $\pi^L_{\tilde{A}_S}(u) = \pi^U_{\tilde{A}_S}(u)$ then, IVSFS $\tilde{A}_S$ lessens to a unique valued SFS.

The pair of $\langle[\mu^L_{\tilde{A}_S}(u), \mu^U_{\tilde{A}_S}(u)], [v^L_{\tilde{A}_S}(u), v^U_{\tilde{A}_S}(u)], [\pi^L_{\tilde{A}_S}(u), \pi^U_{\tilde{A}_S}(u)]\rangle$ is labeled an IVSFN. $\langle[\mu^L_{\tilde{A}_S}(u), \mu^U_{\tilde{A}_S}(u)], [v^L_{\tilde{A}_S}(u), v^U_{\tilde{A}_S}(u)], [\pi^L_{\tilde{A}_S}(u), \pi^U_{\tilde{A}_S}(u)]\rangle$ is presented by $\tilde{\alpha} = \langle[a, b], [c, d], [e, f]\rangle$where $[a,b] \subset [0,1], [c,d] \subset [0,1], [e,f] \subset [0,1]$and $b^2 + d^2 + f^2 \le 1$.

$\tilde{\alpha}^* = \langle[1,1], [0,0], [0,0]\rangle$ is the greatest IVSFS while IVSFS, $\alpha^- = \langle[0,0], [1,1], [0,0]\rangle$ is the littlest and $\tilde{\alpha}^{*/-} = \langle[0,0], [0,0], [1,1]\rangle$ is between greatest and littlest IVSFN.

Definition 4.2: Let, $\tilde{\alpha} = \langle[a, b], [c, d], [e, f]\rangle, \tilde{\alpha}_1 = \langle[a_1, b_1], [c_1, d_1], [e_1, f_1]\rangle$, and $\tilde{\alpha}_2 = \langle[a_2, b_2], [c_2, d_2], [e_2, f_2]\rangle$ be IVSFSs then:

$$\tilde{\alpha}_1 \cup \tilde{\alpha}_2 = \{[max\{a_1, a_2\}, max\{b_1, b_2\}], [min\{c_1, c_2\}, min\{d_1, d_2\}], [min\{e_1, e_2\}, min\{f_1, f_2\}]\} \quad \mathbf{(2)}$$

$$\tilde{\alpha}_1 \cap \tilde{\alpha}_2 = \{[min\{a_1, a_2\}, min\{b_1, b_2\}], [max\{c_1, c_2\}, max\{d_1, d_2\}], [min\{e_1, e_2\}, min\{f_1, f_2\}]\} \quad \mathbf{(3)}$$

$$\tilde{\alpha}_1 \oplus \tilde{\alpha}_2 = \left\{\begin{matrix}\left[((a_1)^2 + (a_2)^2 - (a_1)^2(a_2)^2)^{1/2}, ((b_1)^2 + (b_2)^2 - (b_1)^2(b_2)^2)^{1/2}\right], [c_1c_2, d_1d_2], \\ \left[\left((1 - (a_2)^2)(e_1)^2 + (1 - (a_1)^2)(e_2)^2 - (e_1)^2(e_2)^2\right)^{1/2}, \left((1 - (b_2)^2)(f_1)^2 + (1 - (b_1)^2)(f_2)^2 - (f_1)^2(f_2)^2\right)^{1/2}\right]\end{matrix}\right\} \quad \mathbf{(4)}$$

$$\tilde{\alpha}_1 \otimes \tilde{\alpha}_2 = \left\{ \begin{matrix} [a_1 a_2, b_1 b_2], \left[((c_1)^2 + (c_2)^2 - (c_1)^2 (c_2)^2)^{1/2}, ((d_1)^2 + (d_2)^2 - (d_1)^2 (d_2)^2)^{1/2}\right] \\ \left[\left((1-(c_2)^2)(e_1)^2 + (1-(c_1)^2)(e_2)^2 - (e_1)^2(e_2)^2\right)^{1/2}, \left((1-(d_2)^2)(f_1)^2 + (1-(d_1)^2)(f_2)^2 - (f_1)^2(f_2)^2\right)^{1/2}\right] \end{matrix} \right\}$$

(5)

Multiplication by a scalar; $\lambda \geq 0$

$$\lambda \cdot \tilde{\alpha} = \left\{ \left[\left(1-(1-a^2)^\lambda\right)^{1/2}, \left(1-(1-b^2)^\lambda\right)^{1/2}\right], [c^\lambda, d^\lambda], \left[\left((1-a^2)^\lambda - (1-a^2-e^2)^\lambda\right)^{1/2}, \left((1-b^2)^\lambda - (1-b^2-f^2)^\lambda\right)^{1/2}\right] \right\} \quad \textbf{(6)}$$

λ^{th} Power of $\tilde{\alpha}$; $\lambda \geq 0$

$$\tilde{\alpha}^\lambda = \left\{ [a^\lambda, b^\lambda], \left[\left(1-(1-c^2)^\lambda\right)^{1/2}, \left(1-(1-d^2)^\lambda\right)^{1/2}\right], \left[\left((1-c^2)^\lambda - (1-c^2-e^2)^\lambda\right)^{1/2}, \left((1-d^2)^\lambda - (1-d^2-f^2)^\lambda\right)^{1/2}\right] \right\} \quad \textbf{(7)}$$

Definition 4.3: Let $\tilde{\alpha}_j = \langle [a_j, b_j], [c_j, d_j], [e_j, f_j] \rangle$ be a group of Interval-Valued Spherical Weighted Arithmetic Mean (IVSWAM) concerning $w_j = (w_1, w_2, \ldots, w_n)$; $w_j \in [0,1]$ and $\sum_{j=1}^n w_j = 1$, IVSWAM is expressed as;

$$\text{IV } SWAM_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \ldots \cdots, \tilde{\alpha}_n) = w_1 \cdot \tilde{\alpha}_1 \oplus w_2 \cdot \tilde{\alpha}_2 \oplus \cdots \cdots \oplus w_n \cdot \tilde{\alpha}_n$$
$$= \left\{ \left[\left(1-\prod_{j=1}^n (1-a_j^2)^{w_j}\right)^{1/2}, \left(1-\prod_{j=1}^n (1-b_j^2)^{w_j}\right)^{1/2}\right], \left[\prod_{j=1}^n c_j^{w_j}, \prod_{j=1}^n d_j^{w_j}\right] \right.$$
$$\left. \times \left[\left(\prod_{j=1}^n (1-a_j^2)^{w_j} - \prod_{j=1}^n (1-a_j^2-e_j^2)^{w_j}\right)^{1/2}, \left(\prod_{j=1}^n (1-b_j^2)^{w_j} - \prod_{j=1}^n (1-b_j^2-f_j^2)^{w_j}\right)^{1/2}\right] \right\} \quad \textbf{(8)}$$

Definition 4.4: Let $\tilde{\alpha}_j = \langle [a_j, b_j], [c_j, d_j], [e_j, f_j] \rangle$ be a group of Interval-Valued Spherical Geometric Mean (IVSWGM) regarding $w_j = (w_1, w_2, \ldots \ldots, w_n)$; $w_j \in [0,1]$ and $\sum_{j=1}^n w_j = 1$, IVSWGM is expressed as;

$$IVSWGM_w(\tilde{\alpha}_1, \tilde{\alpha}_2 \ldots \ldots, \tilde{\alpha}_n) = \tilde{\alpha}_1^{w_1} \otimes \tilde{\alpha}_2^{w_2} \otimes \cdots \cdots \otimes \tilde{\alpha}_n^{w_n}$$
$$= \left\{ \left[\prod_{j=1}^n a_j^{w_j}, \prod_{j=1}^n b_j^{w_j}\right], \left[\left(1-\prod_{j=1}^n (1-c_j^2)^{w_j}\right)^{1/2}, \left(1-\prod_{j=1}^n (1-d_j^2)^{w_j}\right)^{1/2}\right], \right.$$
$$\left. \left[\left(\prod_{j=1}^n (1-c_j^2)^{w_j} - \prod_{j=1}^n (1-c_j^2-e_j^2)^{w_j}\right)^{1/2}, \left(\prod_{j=1}^n (1-d_j^2)^{w_j} - \prod_{j=1}^n (1-d_j^2-f_j^2)^{w_j}\right)^{1/2}\right] \right\} \quad \textbf{(9)}$$

Definition 4.5: The score function of the IVSFS number α is determined as

$$\text{Score } (\tilde{\alpha}) = S(\tilde{\alpha}) = \frac{a^2+b^2-c^2-d^2-(e/2)^2-(f/2)^2}{2} \quad \textbf{(10)}$$

where $Score\ (\tilde{\alpha}) = S(\tilde{\alpha}) \in [-1, +1]$. The greater the $S(\tilde{\alpha})$ indicates the larger α.When $S(\tilde{\alpha}) = 1$ then $\tilde{\alpha} = \langle [1,1], [0,0], [0,0] \rangle$; when $S(\tilde{\alpha}) = -1$ then α is the smallest IVSFS number $\tilde{\alpha} = \langle [0,0], [1,1], [0,0] \rangle$.

4.2. IVSF SWARA

The steps of the IVSF SWARA approach can be presented in the following steps (Aghdaie et al., 2013; Ighravwe & Oke, 2019; Keshavarz-Ghorabaee et al., 2018):

Step 1. The problem is evaluated through criteria

Step 2. Criteria are classified in descending order by experts using IVSFS linguistic scale which allows more flexibility during the procedure, as practical problems are uncertain. **Table 6** presents the evaluation scale in this form.

Table 6. Linguistic terms

Linguistic terms	IVSF number	Score index
Absolutely more important (AMI)	([0.85, 0.95], [0.10, 0.15], [0.05, 0.15])	9,00
Very high important (VHI)	([0.75, 0.85], [0.15, 0.20], [0.15, 0.20])	7,00
High important (HI)	([0.65, 0.75], [0.20, 0.25], [0.20, 0.25])	5,00
Slightly more important (SMI)	([0.55, 0.65], [0.25, 0.30], [0.25, 0.30])	3,00
Equally important (EI)	([0.50, 0.55], [0.45, 0.55], [0.30, 0.40])	1,00
Slightly low important (SLI)	([0.25, 0.30], [0.55, 0.65], [0.25, 0.30])	0,33
Low important (LI)	([0.20, 0.25], [0.65, 0.75], [0.20, 0.25])	0,20
Very low important (VLI)	([0.15, 0.20], [0.75, 0.85], [0.15, 0.20])	0,14
Absolutely low important (ALI)	([0.10, 0.15], [0.85, 0.95], [0.05, 0.15])	0,11

The weight matrix can be created as in Eq. (11):

$$\tilde{W} = \begin{bmatrix} \tilde{\alpha}_{11} & \tilde{\alpha}_{12} & \cdots & \tilde{\alpha}_{1t} \\ \tilde{\alpha}_{j1} & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & \vdots \\ \tilde{\alpha}_{n1} & \cdots & \cdots & \tilde{\alpha}_{nt} \end{bmatrix} \quad (\mathbf{11})$$

where n – numbers of criteria, t-experts.

Step 3. Aggregation of experts' opinions based on the arithmetic means of corresponding scores. For that, IVSWAM in Eq. (8) is applied for the weights of experts.

Step 4. The calculation of positive score values is carried through the score function IVSF weights in Eq. (12) (Kutlu Gündoğdu & Kahraman, 2021).

$$\mathrm{s}_j = \mathrm{Score}\left(\tilde{\alpha}_j\right) + 1 \quad (\mathbf{12})$$

Step 5. The rank of criteria is done based on the positive score values.

Step 6. The relative importance c_j of each criterion is derived from the 2nd adopted criteria by assessing positive score values s_j of criterion j and $j-1$.

Step 7. The coefficient k_j is computed.

$$k_j = \begin{cases} 1 & j = 1 \\ \mathrm{c}_j + 1 & j > 1 \end{cases} \quad (\mathbf{13})$$

Step 8. The determination of unnormalized weights q_j is:

$$q_j = \begin{cases} 1 & j = 1 \\ \frac{\mathrm{x}_{j-1}}{\mathrm{k}_j} & j > 1 \end{cases} \quad (\mathbf{14})$$

Step 9. The unnormalized weights of the criteria are normalized and their relative weights are achieved.

$$\mathrm{w}_j = \frac{q_j}{\sum_{j=1}^{n} q_k} \quad (\mathbf{15})$$

4.3. IVSF TOPSIS

The **IVSF** TOPSIS approach includes the following steps:

Step 10: The alternative evaluation matrix is constructed by experts who used **Table 6**.

Step 11: Once all alternative evaluations have been determined by all experts, the IVSWAM operator as outlined in Eq. (8) will be used to calculate the arithmetic mean of the evaluations for each alternative.

Step 12: The weighted IVSF decision matrix will be created, using Eq. (6) to incorporate the criteria weights and alternative ratings. This matrix represents the final decision-making tool for ranking the alternatives.

$$D = \left(C_j(X_{iw})\right)_{mxn} = \begin{pmatrix} ([\mu^L_{11w^L}(u), \mu^U_{11w}(u)], [v^L_{11w}(u), v^U_{11w}(u)], [\pi^L_{11w}(u), \pi^U_{11w}(u)]) & \cdots & ([\mu^L_{1nw}(u), \mu^U_{1nw}(u)], [v^L_{1nw}(u), v^U_{1nw}(u)], [\pi^L_{1nw}(u), \pi^U_{1nw}(u)]) \\ ([\mu^L_{22w}(u), \mu^U_{22w}(u)], [v^L_{22w}(u), v^U_{22w}(u)], [\pi^L_{22w}(u), \pi^U_{22w}(u)]) & \cdots & ([\mu^L_{2nw}(u), \mu^U_{2nw}(u)], [v^L_{2nw}(u), v^U_{2nw}(u)], [\pi^L_{2nw}(u), \pi^U_{2nw}(u)]) \\ & = & . \\ ([\mu^L_{m1w}(u), \mu^U_{m1w}(u)], [v^L_{m1w}(u), v^U_{m1w}(u)], [\pi^L_{m1w}(u), \pi^U_{m1}(u)]) & \cdots & [\mu^L_{mnw}(u), \mu^U_{mnw}(u)], [v^L_{mnw}(u), v^U_{mnw}(u)], [\pi^L_{mnw}(u), \pi^U_{mnw}(u)] \end{pmatrix} \quad \mathbf{(16)}$$

Step 13. The score assigned to the parameter of the weighted IVSF decision matrix is calculated using Eq. (17), which is derived from Eq. (10).

$$S\left(C_j(X_{iw})\right) = \text{Score } \left(C_j(X_{iw})\right) + 1 \quad (\mathbf{17})$$

Step 14. The IVSF Positive Ideal Solution (PIS) and the IVSF Negative Ideal Solution (IVSF-NIS) are determined using score values from Step 9. The IVSF-PIS is shown in Eq. (18).

$$X^* = \left\{C_j, \underset{i}{max} < S\left(C_j(X_{iw})\right) > \mid j = 1,2 \ldots n\right\} \quad (\mathbf{18})$$

$$X^* = \begin{cases} \langle C_1, ([\mu_1^{L^*}, \mu_1^{U^*}], [v_1^{L^*}, v_1^{U^*}], [\pi_1^{L^*}, \pi_1^{U^*}])\rangle, \left\langle C_2, \left([\mu_2^{L^*}, \mu_2^{U^*}], \left[v_2^{L^*_*,}, v_2^{U^*}\right], [\pi_2^{L^*}, \pi_2^{U^*}]\right)\right\rangle \\ \qquad \ldots \ldots \left\langle C_n, \left([\mu_n^{L^*}, \mu_n^{U^*}], \left[[v_n^{L^*}, v_n^{U^*}], [\pi_n^{L^*}, \pi_n^{U^*}]\right)\right\rangle\right\} \end{cases} \quad (\mathbf{19})$$

The IVSF-NIS is shown in Eq. (20):

$$X^- = \left\{C_j, \underset{i}{min} < S\left(C_j(X_{iw})\right)\right\rangle \mid j = 1,2 \ldots n\right\} \quad (\mathbf{20})$$

$$x^- = \left\{\begin{matrix} \langle C_1, ([\mu_1^{L-}, \mu_1^{U-}], [v_1^{L-}, v_1^{U-}], [\pi_1^{L-}, \pi_1^{U-}])\rangle, \langle C_2, ([\mu_2^{L-}, \mu_2^{U-}], [v_2^{L-}, v_2^{U-}], [\pi_2^{L-}, \pi_2^{U-}])\rangle \\ \ldots \ldots \langle C_n, ([\mu_n^{L-}, \mu_n^{U-}], [v_n^{L-}, v_n^{U-}], [\pi_n^{L-}, \pi_n^{U-}])\rangle \end{matrix}\right\} \quad (\mathbf{21})$$

Step 15. The distances between each alternative Xi and the IVSF-PIS and IVSF-NIS using a specific equation (Eq. 22) are calculated.

$$d(X_{ij}, X_j^+) = \frac{1}{4n}\sum_{j=1}^{n} \left(\left|(\mu_{ij}^L)^2 - (\mu_j^+)^2\right| + \left|(\mu_{ij}^U)^2 - (\mu_j^+)^2\right| + \left|(v_{ij}^L)^2 - (v_j^+)^2\right| + \left|(v_{ij}^U)^2 - (v_j^+)^2\right| + \left|(\pi_{ij}^L)^2 - (\pi_j^+)^2\right| + \left|(\pi_{ij}^U)^2 - (\pi_j^+)^2\right|\right) \forall i \quad (\mathbf{22})$$

The distance to IVSF-NIS is given by Eq. (23):

$$d(x_{ij}, X_j^-) = \frac{1}{4n}\sum_{j=1}^{n} \left(\left|(\mu_{ij}^L)^2 - (\mu_j^-)^2\right| + \left|(\mu_{ij}^U)^2 - (\mu_j^-)^2\right| + \left|(v_{ij}^L)^2 - (v_j^-)^2\right| + \left|(v_{ij}^U)^2 - (v_j^-)^2\right| + \left|(\pi_{ij}^L)^2 - (\pi_j^-)^2\right| + \left|(\pi_{ij}^U)^2 - (\pi_j^-)^2\right|\right) \forall i \quad (\mathbf{23})$$

Step 16. The closeness ratio is determined using equation Eq. (24).

$$Closeness\ Ratio_i = \frac{d\left(x_{ij}, x_j^-\right)}{d\left(x_{ij}, x_j^-\right) + d\left(x_{ij}, x_j^+\right)} \quad \textbf{(24)}$$

Step 17. A suitable option is found based on the comparison of the closeness ratios calculated in the previous step. The flowchart in **Figure 1** provides a visual representation of the entire process, highlighting the integration of the IVSF approach.

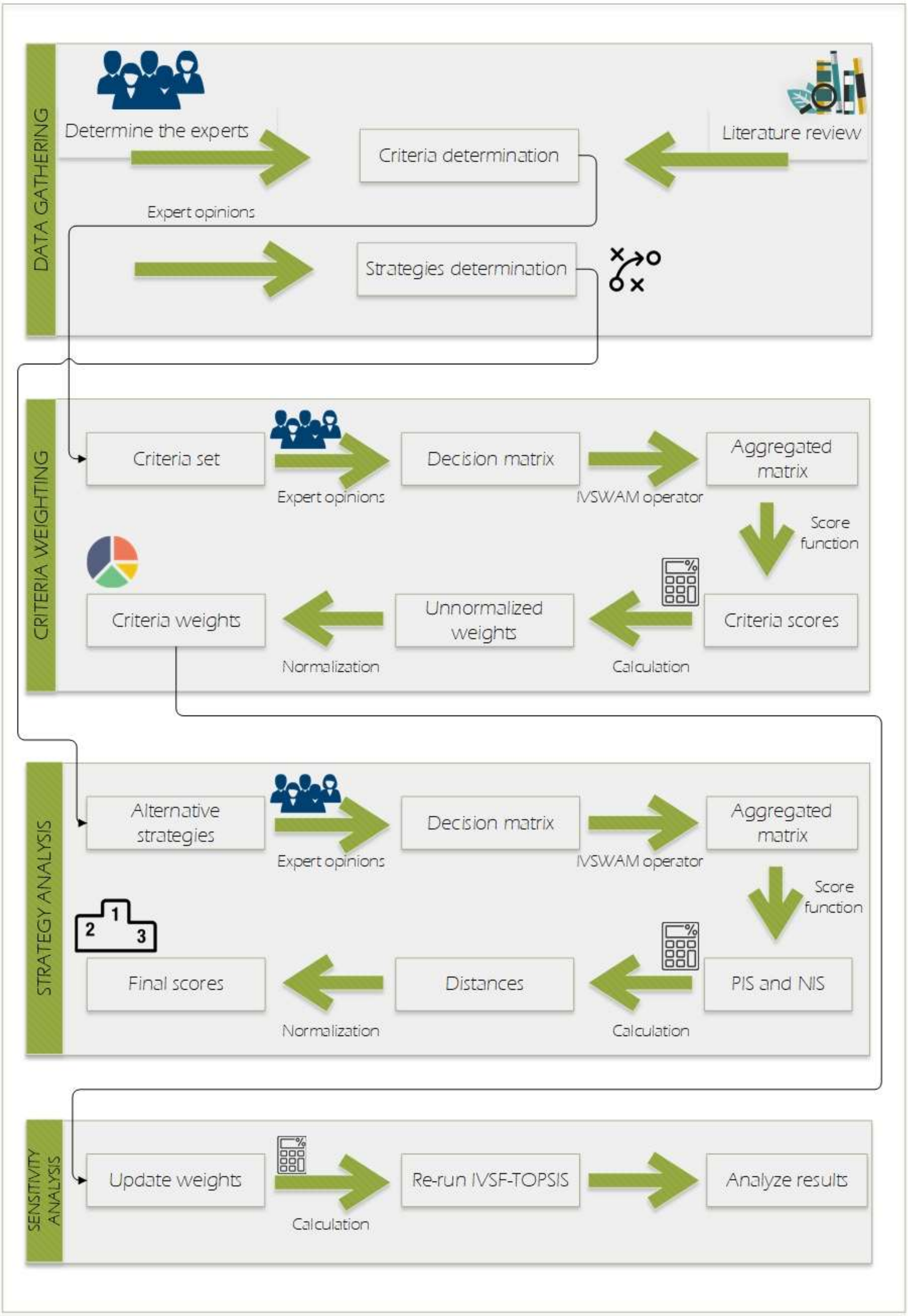

Figure 1. Flowchart of the applied approach

5. Application

A method has been put forward to tackle the challenges of properly coordinating institutional efforts in public transportation planning in Nairobi using a multi-criteria approach. Through literature review and expert inputs, seven significant challenges along with their potential solutions were identified (see Section 3). **The** information about the backgrounds of the experts involved in the study is shown (**Table 7**).

Table 7. Background information of experts

Expert	Gender	Occupation	Degree	Experience
E-1	Male	Academia	Ph.D.	15
E-2	Female	Industry	M.Sc.	20
E-3	Male	Industry	M.Sc.	17
E-4	Male	Academia	Ph.D.	10

Based on the hierarchical structure depicted in **Figure 2**, data were gathered using **Table 6** from experts**.**

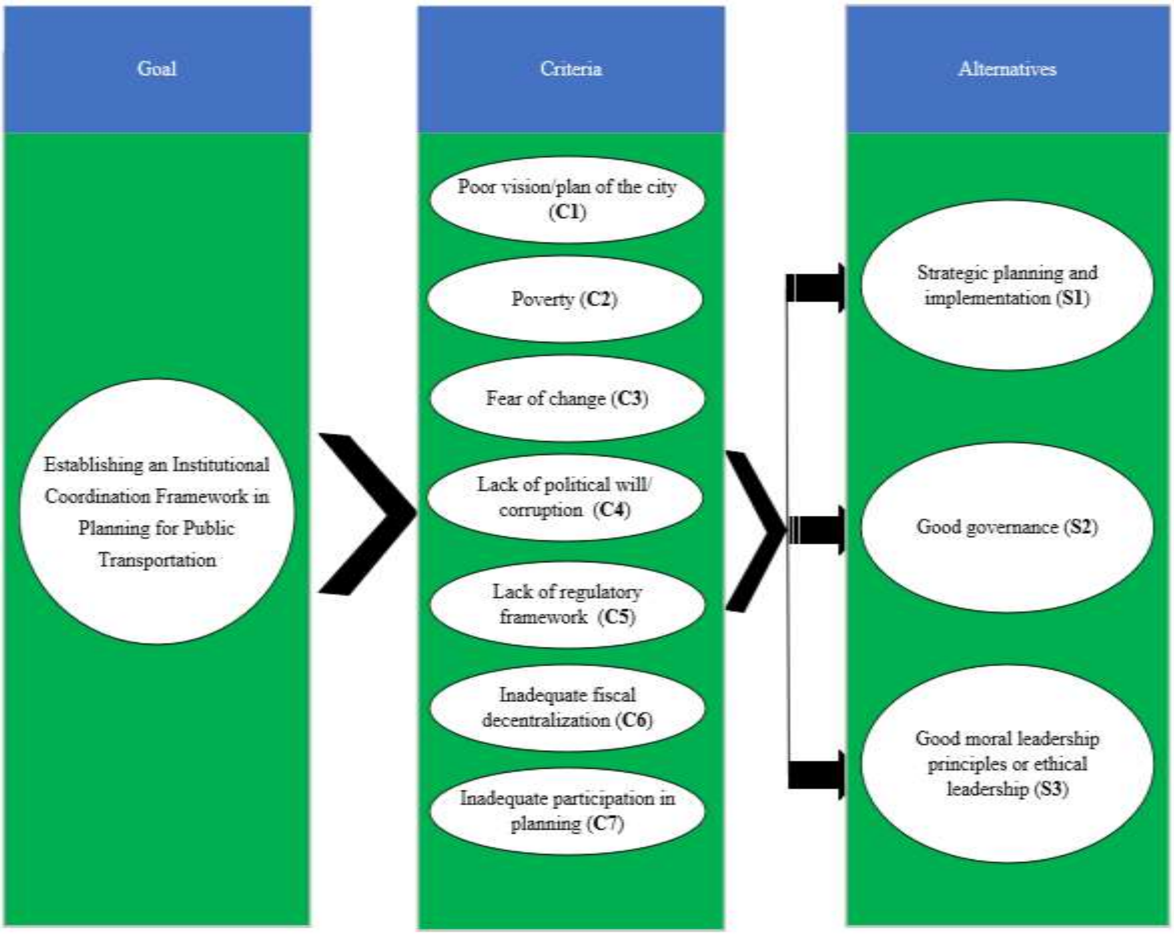

Figure 2. The framework of assessing and evaluating challenges to adequate institutional coordination for public transportation planning.

5.1. Prioritizing the criteria

Step 1. The identified seven criteria are determined to analyze strategies to improve coordination in planning for public transportation.

Step 2. Four experts are consulted to determine criteria weights based on the criteria assessments (**Table 8**).

Table 8. Criteria assessment

Criteria	E-1	E-2	E-3	E-4
Poor vision/plan of the city (C1)	HI	HI	HI	HI
Poverty (C2)	EI	EI	LI	SLI
Fear of change (C3)	SLI	HI	LI	SLI
Lack of political will/corruption (C4)	VHI	VHI	AMI	AMI
Lack of regulatory framework (C5)	LI	VHI	VHI	HI
Inadequate fiscal decentralization (C6)	SMI	EI	EI	SLI
Inadequate participation in planning (C7)	SMI	VHI	HI	HI

Note: E: Expert.

Step 3. Firstly, mathematical expressions are used to transform the linguistic variables based on **Table 6**. Then experts' opinions are aggregated (see **Table 9**). At this step, all experts are assumed to have equal weights.

Table 9. Aggregated evaluations of criteria

Criteria	a	b	c	d	e	f
C1	0.6500	0.7500	0.2000	0.2500	0.0400	0.0625
C2	0.3956	0.4442	0.5187	0.6197	0.0740	0.1279
C3	0.4056	0.4864	0.4453	0.5305	0.0511	0.0781
C4	0.8072	0.9141	0.1225	0.1732	0.0106	0.0310
C5	0.6552	0.7605	0.2326	0.2943	0.0305	0.0527
C6	0.4704	0.5375	0.4085	0.4928	0.0774	0.1281
C7	0.6597	0.7626	0.1968	0.2475	0.0395	0.0613

Step 4. The calculation of positive scores for criteria is provided (**Table 10**).

Table 10. Positive scores of criteria

	C1	C2	C3	C4	C5	C6	C7
s_j	1.4406	0.8477	0.9596	1.7209	1.4330	1.0474	1.4577

Step 5. Criteria are ordered as $C4 > C7 > C1 > C5 > C6 > C3 > C2$.

Step 6. The comparative significances of the criteria are calculated (**Table 11**).

Table 11. Comparative significances of criteria

	C4	**C7**	**C1**	**C5**	**C6**	**C3**	**C2**
c_j	-	0.2632	0.0171	0.0075	0.3856	0.0878	0.1119

Step 7. The computation of the coefficients is made (**Table 12**)

Table 12. Coefficients for criteria

	C4	**C7**	**C1**	**C5**	**C6**	**C3**	**C2**
k_j	1	1.2632	1.0171	1.0075	1.3856	1.0878	1.1119

Step 8. The computation of unnormalized criteria weights is presented (**Table 13**).

Table 13. Unnormalized criteria weights

	C4	**C7**	**C1**	**C5**	**C6**	**C3**	**C2**
q_j	1	0.7916	0.7783	0.7725	0.5575	0.5125	0.4609

Step 9. The calculation of final weights is made (**Figure 3**).

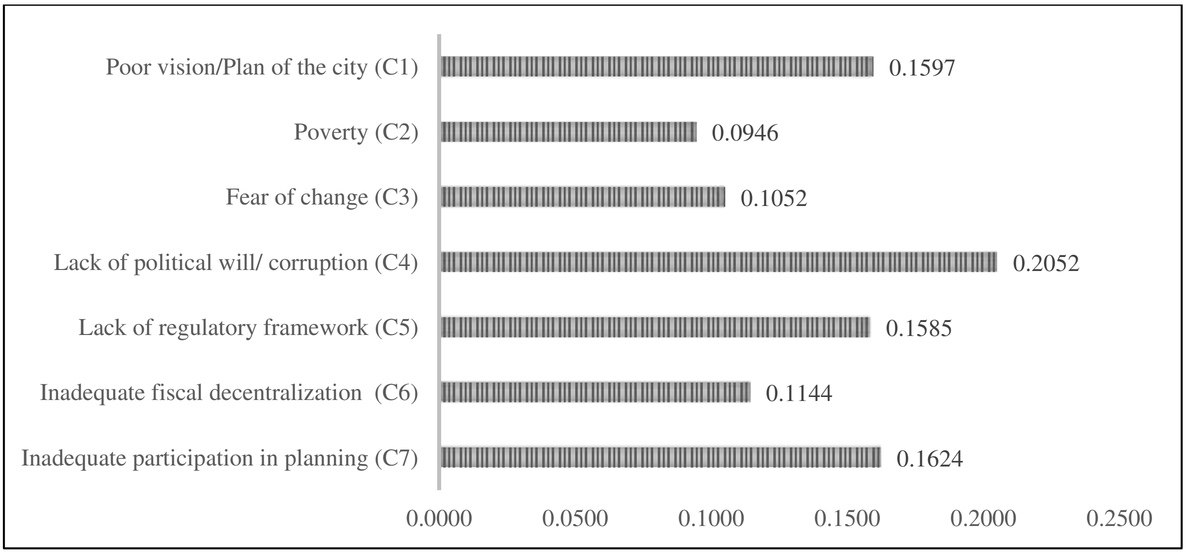

Figure 3. Final criteria weights

As shown in **Figure 3**, experts identified a lack of political will and corruption as a very critical challenge (0.2052), then, inadequate participation in planning (0.1624), poor vision/plan of the city (0.1597), lack of regulatory framework (0.1585), inadequate fiscal decentralization (0.1144), fear of change (0.1052), and poverty (0.0946). The results in **Figure 3** indicate that experts placed significant emphasis on the political and corruption issues. This aligns with the findings of Okpala (2009) who argued that corruption and lack of political commitment are prevalent in sub-Saharan Anglo-African cities and decision-makers who engage in corruption use government resources for personal gain. These actions erode social capital as affected communities believe that corrupt and unethical decision-makers will ultimately waste their local development efforts (Simone, 2002).

The second most significant challenge is inadequate participation in public transportation planning. Our results are comparable to those of Kanyama (2016), who claimed that no institution in Nairobi was entirely taken into consideration when planning for public transportation based on the results of interviews. For instance, Blue Shield Insurance involved parties in Nairobi believed that their insurance responsibility was essential to the public transportation sector, but they were never consulted when planning.

5.2. Analyzing the strategies

Step 10. The construction of an alternative evaluation matrix from experts is indicated (**Table 14** in the Appendix).

Step 11. Then experts' opinions are aggregated assuming that all experts have the same weights again. **Table 15 (Appendix)** presents the aggregated evaluation of alternative strategies.

Step 12. The computation of the weighted evaluation matrix (**Table 16 in the Appendix**) is shown based on the aggregated strategy evaluation matrix and criteria weights.

Step 13. The weighted IVSF decision matrix is defuzzified via Eq. 17 and given in **Table 17 (Appendix)** to determine the IVSF-PIS and IVSF-NIS.

Step 14. The determination of IVSF-PIS and IVSF-NIS for criteria are shown (**Table 18 in Appendix**).

Step 15. The calculation of distances to IVSF-PIS and IVSF-NIS are presented (**Table 19**) via Eq. 22 and Eq 23, respectively.

Table 19. The distance between alternatives and ideal solutions

	Distance to IVSF-PIS			**Distance to IVSF-NIS**		
	S1	S2	S3	S1	S2	S3
C1	0	0.0532	0.3485	0.3485	0.2958	0
C2	0.3454	0	0.1746	0	0.3454	0.1708
C3	0.2138	0	0.0123	0	0.2138	0.2015
C4	0.7789	0	0	0	0.7789	0.7789
C5	0.2474	0	0.2482	0.0171	0.2482	0
C6	0.3110	0	0.0983	0	0.3110	0.2127
C7	0.0374	0	0.3409	0.3035	0.3409	0

Step 16. The determination of the closeness ratio via Eq. (24) is made (**Table 20**).

Table 20. Final scores of strategies

	S1	**S2**	**S3**
d (X_{ij}, X_j^{+})	0.4835	0.0133	0.3057
d (X_{ij}, X_j^{-})	0.1673	0.6335	0.3410
Closeness Ratio	0.2571	0.9794	0.5273

Step 17. Strategies are ordered in descending order according to the closeness ratio. The most appropriate strategy is found to be strategy 2, followed by strategy 3 which took the second position. Strategy 1 remains the least appropriate strategy.

6. Sensitivity analysis

The strategy ranking is greatly impacted by the weight assigned to specific criteria. Even minor modifications in these weights can produce significant changes in the final result. Given that these weights are usually based on the subjective views of experts, it's crucial to assess the ranking's stability when the weights are adjusted. To ensure the stability of the ranking, sensitivity analysis can be performed through scenarios that simulate future events or reflect varying views on the criteria's importance. This enables monitoring of shifts in priorities and the ranking of alternatives when the criteria weights are adjusted. The sensitivity analysis sheds light on the ranking's dependability. If the ranking is highly susceptible to slight changes in the criteria weights, it is advisable to conduct a thorough review of them.

The sensitivity analysis is conducted to confirm the validity of the results by changing the criteria weights and simulating weights from 0% to 100%. This is achieved by adjusting the weight of each criterion separately while keeping in mind that the total weight must equal 100%. The analysis also incorporates variations in the local priority weights of the subjective elements, as adjusting the importance of criteria demands adjusting the contribution of each criterion to ensure the strategies are chosen based on the predefined criteria.

The sensitivity of the institutional coordination challenge is evaluated by modifying the weights of the three most crucial selection criteria (C1, C4, and C7) by a range of 10% to 30%, and then recalculating the final scores of the strategies using the IVSF-TOPSIS method. The findings of the sensitivity analysis are displayed in **Table 21**, which demonstrates the consistency of the results.

Table 21. Sensitivity analysis outcomes

Criteria	**Increasing**	**S1**		**S2**		**S3**	
		Score	**Rank**	**Score**	**Rank**	**Score**	**Rank**

	Original	0.2571	3	0.9794	1	0.5273	2
C1	10%	0.2657	3	0.9779	1	0.5212	2
	20%	0.2740	3	0.9765	1	0.5153	2
	30%	0.2819	3	0.9751	1	0.5097	2
C4	10%	0.2512	3	0.9799	1	0.5382	2
	20%	0.2457	3	0.9804	1	0.5484	2
	30%	0.2406	3	0.9808	1	0.5580	2
C7	10%	0.2637	3	0.9797	1	0.5217	2
	20%	0.2701	3	0.9799	1	0.5165	2
	30%	0.2762	3	0.9801	1	0.5115	2

7. Discussion and policy implications

This study presents a real-life examination in which the challenges in effectively implementing proper institutional coordination in public transportation planning are identified and categorized based on their level of criticality, and strategies to overcome these challenges are prioritized. First and foremost, criteria evaluation is conducted to prioritize strategies. For this reason, the challenges (criteria) are weighed using the SWARA by applying the IVSF theory, which illustrates the uncertainty in expert evaluations. TOPSIS is used to rank strategies in the IVSF setting. To choose the most appropriate strategy, a hybrid SWARA-TOPSIS method is used in an IVSF setting. Through antecedent studies and experts' viewpoints, the proposed hybrid method evaluates criteria and strategies for effectively implementing proper institutional coordination in public transportation planning. In this regard, the challenges are evaluated and a strategic framework is established.

The study suggests that a lack of political will and corruption are the biggest challenges to effectively coordinating institutions in public transportation planning. Consequently, there must be robust political commitment and support from all levels of government to ensure effective institutional coordination in public transportation planning. Given that planning public transportation has a political dimension, failing to acknowledge this aspect increases the risk of unfavorable results and undermines the chances of long-term success. Furthermore, it is important to establish strict anti-corruption measures in every stage of public transportation planning.

The second biggest challenge to effective public transportation planning is ineffective involvement during the planning procedure, which is a widespread issue in cities in sub-Saharan Africa, according to Rakodi (2016). This lack of involvement from institutions is assigned to the metropolitan operational and planning model from the colonial era, which is heavily focused on public sector investment and does not involve a diverse range of parties. It is crucial for African leaders to move away from a colonial-influenced, paternalistic attitude and instead embrace citizen participation and power-sharing to strengthen the relationship between the government and civil society. By doing so, the public will be more likely to engage in discussions about urban development and feel that their input is valued in the planning process.

A third major challenge in public transportation planning is the lack of a clear and comprehensive plan for the city. It has been observed that Nairobi lacks the necessary institutional framework for effective land use and transportation planning and that the city's current approach is perpetuating negative patterns of development. This issue can be traced back to the 1960s, highlighting an improper establishment of adequate land and transportation planning governance systems. Furthermore, current planning strategies have been ineffective due to the unexpected increase in population density in certain areas. City officials must develop new planning strategies that are appropriate for the changing socioeconomic and cultural context of the city. To effectively plan for the future, Nairobi needs to gather accurate data to inform the planning process, as the mechanisms of urbanization are constantly changing.

The expert committee identified that the main challenges to the effective coordination of institutions in public transportation planning are ineffective political commitment, corruption, and insufficient participation in the planning process. As a result, the committee determined that the most appropriate strategy for addressing these challenges is focusing on good governance principles (S2 alternative). This strategy prioritizes political representation and the formation of cooperation between the government, private sector, and citizens in public transportation planning, which are essential for an effective institutional coordination framework.

8. Conclusion

This study proposes combining the SWARA and TOPSIS techniques under the IVSFSs environment to tackle the challenges encountered in coordinating among institutions during public transportation planning. The proposed approach is validated by examining a real-life example in Nairobi, revealing that the most significant issues impacting coordination in public transportation planning are the absence of political commitment, corruption, insufficient participation during the procedure in planning, and an inadequate overall plan for the city. The findings of the study indicate that good governance principles are crucial for effectively addressing coordination issues among institutions involved in public transportation planning. This study makes notable contributions in two ways: by providing a rational and systematic approach to selecting the most appropriate strategy for improving coordination in Nairobi, it offers a practical framework for institutional coordination in public transportation planning. Additionally, the newly developed integrated model represents a scientific advancement in the field.

Although this study makes a valuable contribution to understanding institutional coordination in public transportation planning, it also has certain limitations. One limitation is that it did not take into account socio-economic and political factors in its criteria, and only a small number of experts participated in the survey. Another limitation is that the study lacked standards for selecting appropriate experts for data collection.

In the future, studies in public transportation planning should consider the socio-political and technical challenges involved in coordinating institutions. To ensure accurate results, it is essential to involve more experts in the research process. To achieve this, researchers should establish criteria for selecting the appropriate experts. Besides, the application of a linear programming framework (Das et al., 2018; Das et al., 2017; Edalatpanah, 2019) under uncertainty is suggested in establishing future integrated approaches. The currently proposed methodology may be considered in the study of supply chain management and logistics, choice of the contractor during construction, and, sustainable building material choice.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abd Rahman, N. A., & Abdullah, Y. A. (2016). Theorizing the Concept of Urban Public Transportation Institutional Framework in Malaysia. MATEC Web of Conferences,

Abdul, D., & Wenqi, J. (2022). Evaluating appropriate communication technology for smart grid by using a comprehensive decision-making approach fuzzy TOPSIS. Soft Computing, 1-16.

Aghdaie, M. H., Zolfani, S. H., & Zavadskas, E. K. (2013). Decision making in machine tool selection: An integrated approach with SWARA and COPRAS-G methods. Engineering Economics, 24(1), 5-17.

Akram, M., Dudek, W. A., & Ilyas, F. (2019). Group decision-making based on pythagorean fuzzy TOPSIS method. International Journal of Intelligent Systems, 34(7), 1455-1475.

ALCHIN, S., Worsley, T., & Wickersham, T. (2021). Developing strategic approaches to infrastructure planning.

Alkharabsheh, A., Moslem, S., & Duleba, S. (2022). Analyzing public travel demand by a fuzzy analytic hierarchy process model for supporting transport planning. Transport, 1-11.

Asingo, P. O. (2004). The institutional and organizational structure of public road transport in Kenya.

Ayyildiz, E. (2022). Fermatean fuzzy step-wise Weight Assessment Ratio Analysis (SWARA) and its application to prioritizing indicators to achieve sustainable development goal-7. Renewable Energy, 193, 136-148.

Ayyildiz, E., & Taskin Gumus, A. (2021). A novel distance learning ergonomics checklist and risk evaluation methodology: A case of Covid-19 pandemic. Human Factors and Ergonomics in Manufacturing & Service Industries, 31(4), 397-411.

Baç, U. (2020). An integrated SWARA-WASPAS group decision making framework to evaluate smart card systems for public transportation. Mathematics, 8(10), 1723.

Banister, D. (2005). Overcoming barriers to the implementation of sustainable transport. Barriers to Sustainable Transport: Institutions, regulation and sustainability, 54-68.

Bilgili, F., Zarali, F., Ilgün, M. F., Dumrul, C., & Dumrul, Y. (2022). The evaluation of renewable energy alternatives for sustainable development in Turkey using intuitionistic fuzzy-TOPSIS method. Renewable Energy, 189, 1443-1458.

Bilişik, Ö. N., Erdoğan, M., Kaya, İ., & Baraçlı, H. (2013). A hybrid fuzzy methodology to evaluate customer satisfaction in a public transportation system for Istanbul. Total Quality Management & Business Excellence, 24(9-10), 1141-1159.

Blumenberg, E. (2002). Planning for the transportation needs of welfare participants: Institutional challenges to collaborative planning. Journal of planning education and research, 22(2), 152-163.

Bouraima, M. B., Qiu, Y., Stević, Ž., & Simić, V. (2022). Assessment of alternative railway systems for sustainable transportation using an integrated IRN SWARA and IRN CoCoSo model. Socio-Economic Planning Sciences, 101475. https://doi.org/https://doi.org/10.1016/j.seps.2022.101475

Bouraima, M. B., Qiu, Y., Yusupov, B., & Ndjegwes, C. M. (2020). A study on the development strategy of the railway transportation system in the West African Economic and Monetary Union (WAEMU) based on the SWOT/AHP technique. Scientific African, 8, e00388.

Bouraima, M. B., Stević, Ž., Tanackov, I., & Qiu, Y. (2021). Assessing the performance of Sub-Saharan African (SSA) railways based on an integrated Entropy-MARCOS approach. Operational Research in Engineering Sciences: Theory and Applications, 4(2), 13-35.

Bouraima, M. B., Tengecha, N. A., Stević, Ž., Simić, V., & Qiu, Y. (2023). An integrated fuzzy MCDM model for prioritizing strategies for successful implementation and operation of the bus rapid transit system. Annals of Operations Research. https://doi.org/10.1007/s10479-023-05183-y

Buye, R. (2020). Ethical leadership in Public Management: The importance of ethical principles and standards to improve performance in public sector organizations. Internet Encyclopedia of Philosophy" Ethics, 1-14.

Celik, E., Bilisik, O. N., Erdogan, M., Gumus, A. T., & Baracli, H. (2013). An integrated novel interval type-2 fuzzy MCDM method to improve customer satisfaction in public transportation for Istanbul. Transportation Research Part E: Logistics and Transportation Review, 58, 28-51.

Celik, E., GUMUS, A. T., & AYDIN, N. (2016). An intuitionistic fuzzy approach for evaluating service quality of public transportation Systems. Uncertainty Modelling in Knowledge Engineering and Decision Making: Proceedings of the 12th International FLINS Conference,

Das, S. K., Edalatpanah, S., & Mandal, T. (2018). A proposed model for solving fuzzy linear fractional programming problem: Numerical Point of View. Journal of computational science, 25, 367-375.

Das, S. K., Mandal, T., & Edalatpanah, S. (2017). A mathematical model for solving fully fuzzy linear programming problem with trapezoidal fuzzy numbers. Applied Intelligence, 46, 509-519.

Deveci, M. (2022). A Decision Support System for Assessing and Prioritizing Sustainable Urban Transportation in Metaverse. IEEE Transactions on Fuzzy Systems, 1-10. https://doi.org/10.1109/TFUZZ.2022.3190613

Deveci, M., Canıtez, F., & Gökaşar, I. (2018). WASPAS and TOPSIS based interval type-2 fuzzy MCDM method for a selection of a car sharing station. Sustainable Cities and Society, 41, 777-791.

Deveci, M., Pamucar, D., Gokasar, I., & Delen, D. (2022). A fuzzy Einstein-based decision support system for public transportation management at times of pandemic. Knowledge-Based Systems. https://doi.org/10.1016/j.knosys.2022.109414

Edalatpanah, S. A. (2019). A nonlinear approach for neutrosophic linear programming. Journal of applied research on industrial engineering, 6(4), 367-373.

El-Shakhs, S. (1997). Towards Appropriate Urban Development Policy in Emerging Mega-Cities in Africa. The Urban Challenge in Africa: Growth and Management of Its Large Cities. C. Rakodi. In: United Nations University Press, New York, USA.

Erdoğan, M., & Kaya, I. (2016). Evaluating Alternative-Fuel Busses for Public Transportation in Istanbul Using Interval Type-2 Fuzzy AHP and TOPSIS. Journal of Multiple-Valued Logic & Soft Computing, 26(6).

Erdoğan, M., & Kaya, İ. (2020). A systematic approach to evaluate risks and failures of public transport systems with a real case study for bus rapid system in Istanbul. Sustainable Cities and Society, 53, 101951.

Farrokhizadeh, E., Seyfi-Shishavan, S. A., Gündoğdu, F. K., Donyatalab, Y., Kahraman, C., & Seifi, S. H. (2021). A spherical fuzzy methodology integrating maximizing deviation and TOPSIS methods. Engineering Applications of Artificial Intelligence, 101, 104212.

Garg, H., & Kumar, K. (2020). A novel exponential distance and its based TOPSIS method for interval-valued intuitionistic fuzzy sets using connection number of SPA theory. Artificial Intelligence Review, 53(1), 595-624.

Garg, H., Vimala, J., Rajareega, S., Preethi, D., & Perez-Dominguez, L. (2022). Complex intuitionistic fuzzy soft SWARA-COPRAS approach: An application of ERP software selection. AIMS Mathematics, 7(4), 5895-5909.

Gokasar, I., Deveci, M., & Kalan, O. (2021). CO2 Emission based prioritization of bridge maintenance projects using neutrosophic fuzzy sets based decision making approach. Research in Transportation Economics, 101029.

Gokasar, I., Timurogullari, A., Deveci, M., & Garg, H. (2022). SWSCAV: Real-time traffic management using connected autonomous vehicles. ISA transactions. https://doi.org/10.1016/j.isatra.2022.06.025.

Gokasar, I., Timurogullari, A., Özkan, S. S., Deveci, M., & Lv, Z. (2022). MSND: Modified Standard Normal Deviate Incident Detection Algorithm for Connected Autonomous and Human-Driven Vehicles in Mixed Traffic. IEEE Transactions on Intelligent Transportation Systems. https://doi.org/10.1109/TITS.2022.3190667

Görçün, Ö. F. (2021). Evaluation of the selection of proper metro and tram vehicle for urban transportation by using a novel integrated MCDM approach. Science progress, 104(1), 0036850420950120.

Gul, M., & Ak, M. F. (2021). A modified failure modes and effects analysis using interval-valued spherical fuzzy extension of TOPSIS method: case study in a marble manufacturing facility. Soft Computing, 25(8), 6157-6178.

Gul, M., & Yucesan, M. (2021). Hospital preparedness assessment against COVID-19 pandemic: a case study in Turkish tertiary healthcare services. Mathematical Problems in Engineering, 2021.

Gulum, P., Ayyildiz, E., & Gumus, A. T. (2021). A two-level interval valued neutrosophic AHP integrated TOPSIS methodology for post-earthquake fire risk assessment: An application for Istanbul. International Journal of Disaster Risk Reduction, 61, 102330.

Gündoğdu, F. K., & Kahraman, C. (2019). A novel fuzzy TOPSIS method using emerging interval-valued spherical fuzzy sets. Engineering Applications of Artificial Intelligence, 85, 307-323.

Hajduk, S. (2021). Multi-Criteria Analysis in the Decision-Making Approach for the Linear Ordering of Urban Transport Based on TOPSIS Technique. Energies, 15(1), 274.

Hatzopoulou, M., & Miller, E. J. (2008). Institutional integration for sustainable transportation policy in Canada. Transport policy, 15(3), 149-162.

Hirschhorn, F., van de Velde, D., Veeneman, W., & ten Heuvelhof, E. (2020). The governance of attractive public transport: Informal institutions, institutional entrepreneurs, and problem-solving know-how in Oslo and Amsterdam. Research in Transportation Economics, 83, 100829.

Hwang, C.-L., & Yoon, K. (1981). Methods for multiple attribute decision making. In Multiple attribute decision making (pp. 58-191). Springer.

Ighravwe, D. E., & Oke, S. A. (2019). An integrated approach of SWARA and fuzzy COPRAS for maintenance technicians' selection factors ranking. International Journal of System Assurance Engineering and Management, 10(6), 1615-1626.

Ilieva, G., & Yankova, T. (2022). Extension of interval-valued Fermatean fuzzy TOPSIS for evaluating and benchmarking COVID-19 vaccines. Mathematics, 10(19), 3514.

Kahraman, C., Cebi, S., Onar, S. C., & Öztayşi, B. (2022). Pharmaceutical 3PL supplier selection using interval-valued intuitionistic fuzzy TOPSIS. Proceedings of the 25th Jubilee Edition, 28(3), 361-374.

Kane, L. (2002). The urban transport problem in South Africa and the developing world: A focus on institutional issues. Urban Transport Research Group Working Paper, 3, 1-22.

Kanyama, A. (2016). Challenges of Institutional Coordination in Planning for Public Transportation in East Africa: Analysis Based on Perceptions of Stakeholders in Dar-es-Salaam and Nairobi. World, 3(3).

Kanyama, A., Carlsson-Kanyama, A., & Lindén, A.-L. (2006). Citizen Participation and Institutional Coordination: an examination of public transport and land use planning in Dar-es-Salaam, Tanzania. KTH.

Kanyama, A., Carlsson-Kanyama, A., Lindén, A.-L., & Lupala, J. (2005). An Analysis of the Situation in Dar-es-Salaam in Tanzania from an Institutional Coordination Perspective. In Urban Transport Development (pp. 65-85). Springer.

Kanyama, A. A., & Cars, G. (2009). In search of a framework for institutional coordination in the planning for public transportation in sub-Saharan African cities: an analysis based on experiences from Dar-es Salaam and Nairobi. Department of urban planning and environment, Royal Institute of Technology.

Keršuliene, V., Zavadskas, E. K., & Turskis, Z. (2010). Selection of rational dispute resolution method by applying new step-wise weight assessment ratio analysis (SWARA). Journal of business economics and management, 11(2), 243-258.

Keshavarz-Ghorabaee, M., Amiri, M., Zavadskas, E. K., Turskis, Z., & Antucheviciene, J. (2018). An extended step-wise weight assessment ratio analysis with symmetric interval type-2 fuzzy sets for determining the subjective weights of criteria in multi-criteria decision-making problems. Symmetry, 10(4), 91.

Kim, G., Park, C. S., & Yoon, K. P. (1997). Identifying investment opportunities for advanced manufacturing systems with comparative-integrated performance measurement. International Journal of Production Economics, 50(1), 23-33.

Klopp, J. M. (2012). Towards a political economy of transportation policy and practice in Nairobi. Urban forum,

Kutlu Gündoğdu, F., & Kahraman, C. (2019). Spherical fuzzy sets and spherical fuzzy TOPSIS method. Journal of intelligent & fuzzy systems, 36(1), 337-352.

Kutlu Gündoğdu, F., & Kahraman, C. (2021). Hospital performance assessment using interval-valued spherical fuzzy analytic hierarchy process. In Decision Making with Spherical Fuzzy Sets (pp. 349-373). Springer.

Linehan, D. (2007). Re-ordering the urban archipelago: Kenya Vision 2030, street trade and the battle for Nairobi city centre. Aurora, 1, 21-37.

Matić, B., Marinković, M., Jovanović, S., Sremac, S., & Stević, Ž. (2022). Intelligent Novel IMF D-SWARA—Rough MARCOS Algorithm for Selection Construction Machinery for Sustainable Construction of Road Infrastructure. Buildings, 12(7), 1059.

Mishra, A. R., Rani, P., Pandey, K., Mardani, A., Streimikis, J., Streimikiene, D., & Alrasheedi, M. (2020). Novel multi-criteria intuitionistic fuzzy SWARA–COPRAS approach for sustainability evaluation of the bioenergy production process. Sustainability, 12(10), 4155.

Mohammadian, A., Heidary Dahooie, J., Qorbani, A. R., Zavadskas, E. K., & Turskis, Z. (2021). A new multi-attribute decision-making framework for policy-makers by using interval-valued triangular fuzzy numbers. Informatica, 32(3), 583-618.

Nassereddine, M., & Eskandari, H. (2017). An integrated MCDM approach to evaluate public transportation systems in Tehran. Transportation Research Part A: Policy and Practice, 106, 427-439.

Obudho, R. A. (1997). Nairobi: National capital and regional hub. The urban challenge in Africa: Growth and management of its large cities, 292-334.

Okpala, D. (2009). Regional overview of the status of urban planning and planning practice in Anglophone (Sub-Saharan) African countries. Revisiting Urban Planning: Global Report on Human Settlements.

Pajić, V., Andrejić, M., & Kilibarda, M. (2021). Evaluation and selection of KPI in procurement and distribution logistics using SWARA-QFD approach. International Journal For Traffic And Transport Engineering (IJTTE), 11(2), 267-279.

Pamucar, D., Deveci, M., Canıtez, F., & Bozanic, D. (2020). A fuzzy Full Consistency Method-Dombi-Bonferroni model for prioritizing transportation demand management measures. Applied Soft Computing, 87, 105952.

Pamucar, D., Deveci, M., Gokasar, I., & Popovic, M. (2021). Fuzzy Hamacher WASPAS decision-making model for advantage prioritization of sustainable supply chain of electric ferry implementation in public transportation. Environment, Development and Sustainability, 1-40.

Pamucar, D., Deveci, M., Gokasar, I., Tavana, M., & Koppen, M. (2022). A metaverse assessment model for sustainable transportation using ordinal priority approach and Aczel-Alsina norms. Technological Forecasting and Social Change. https://doi.org/10.1016/j.techfore.2022.121778

Rakodi, C. (2016). The urban challenge in Africa. In Managing urban futures (pp. 63-86). Routledge.

Reig-Mullor, J., Garcia-Bernabeu, A., Pla-Santamaria, D., & Vercher-Ferrandiz, M. (2022). Evaluating ESG corporate performance using a new neutrosophic AHP-TOPSIS based approach. Technological and Economic Development of Economy, 28(5), 1242–1266-1242–1266.

Saeidi, P., Mardani, A., Mishra, A. R., Cajas, V. E. C., & Carvajal, M. G. (2022). Evaluate sustainable human resource management in the manufacturing companies using an extended Pythagorean fuzzy SWARA-TOPSIS method. Journal of Cleaner Production, 370, 133380.

Sampaio, B. R., Neto, O. L., & Sampaio, Y. (2008). Efficiency analysis of public transport systems: Lessons for institutional planning. Transportation Research Part A: Policy and Practice, 42(3), 445-454.

Simic, V., Gokasar, I., Deveci, M., & Karakurt, A. (2022). An integrated CRITIC and MABAC based type-2 neutrosophic model for public transportation pricing system selection. Socio-Economic Planning Sciences, 80, 101157.

Simic, V., Gokasar, I., Deveci, M., & Švadlenka, L. (2022). Mitigating Climate Change Effects of Urban Transportation Using a Type-2 Neutrosophic MEREC-MARCOS Model. IEEE Transactions on Engineering Management.

Simone, A. (2002). Principles and realities of urban governance in Africa. Un-Habitat.

Smoke, P. (2003). Decentralization in Africa: goals, dimensions, myths and challenges. Public Administration and Development: The International Journal of Management Research and Practice, 23(1), 7-16.

Stević, Ž., Zavadskas, E. K., Tawfiq, F. M., Tchier, F., & Davidov, T. (2022). Fuzzy Multicriteria Decision-Making Model Based on Z Numbers for the Evaluation of Information Technology for Order Picking in Warehouses. Applied Sciences, 12(24), 12533.

Stewart, M. (2005). Collaboration in multi-actor governance. Urban governance and democracy: Leadership and community involvement, 149-167.

Stough, R. R., & Rietveld, P. (1997). Institutional issues in transport systems. Journal of Transport Geography, 5(3), 207-214.

Tanackov, I., Badi, I., Stević, Ž., Pamučar, D., Zavadskas, E. K., & Bausys, R. (2022). A Novel Hybrid Interval Rough SWARA–Interval Rough ARAS Model for Evaluation Strategies of Cleaner Production. Sustainability, 14(7), 4343.

Tostensen, A., Tvedten, I., & Vaa, M. (2001). The urban crisis, governance and associational life. Associational Life in African Cities: popular responses to the urban crisis, 7-26.

Vrtagić, S., Softić, E., Subotić, M., Stević, Ž., Dordevic, M., & Ponjavic, M. (2021). Ranking Road Sections Based on MCDM Model: New Improved Fuzzy SWARA (IMF SWARA). Axioms, 10(2), 92.

Wekwete, K. H. (1997). 15 Urban management: The recent experience.

Xiang, Z., Naseem, M. H., & Yang, J. (2022). Selection of Coal Transportation Company Based on Fuzzy SWARA-COPRAS Approach. Logistics, 6(1), 7.

Yildiz, A., Guneri, A. F., Ozkan, C., Ayyildiz, E., & Taskin, A. (2022). An integrated interval-valued intuitionistic fuzzy AHP-TOPSIS methodology to determine the safest route for cash in transit operations: a real case in Istanbul. Neural Computing and Applications, 1-16.

Zhang, Z., Zhao, X., Qin, Y., Si, H., & Zhou, L. (2022). Interval type-2 fuzzy TOPSIS approach with utility theory for subway station operational risk evaluation. Journal of Ambient Intelligence and Humanized Computing, 13(10), 4849-4863.

Zhou, X., Chen, C., Tian, H., Wang, L., Yang, Z., & Yang, H. (2021). Time-varying FMEA method based on interval-valued spherical fuzzy theory. Quality and Reliability Engineering International, 37(8), 3713-3729.

Zolfani, S. H., & Chatterjee, P. (2019). Comparative evaluation of sustainable design based on Step-Wise Weight Assessment Ratio Analysis (SWARA) and Best Worst Method (BWM) methods: a perspective on household furnishing materials. Symmetry, 11(1), 74.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Appendix.docx