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# A Robust Hybrid Multi-Criteria Decision-Making Framework for Sustainable Transportation Planning Under Uncertainty

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**ABSTRACT**

This study develops a sustainability oriented multi-criteria decision-making (MCDM) framework to evaluate and compare smart participation and transportation chain initiatives across major cities in Saudi Arabia. The framework integrates several dimensions, including citizen engagement, the incorporation of renewable energy, multimodal transport systems, artificial intelligence driven traffic management, and circular economy practices. To operationalise the assessment, a three stage MCDM approach is employed. The Analytic Hierarchy Process (AHP) is applied to determine the relative importance of the evaluation criteria, the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is utilised to assess alternatives based on their closeness to the ideal solution, and the Preference Ranking Organisation Method for Enrichment Evaluation (PROMETHEE) is used to establish the final ranking of the cities. The sustainability assessment indicates that Riyadh achieves the highest performance level with a score of 0.80, followed by Jeddah with 0.74 and Dammam with 0.68. A sensitivity analysis is conducted to examine the robustness of the framework, confirming the stability of the outcomes, as variations in the weighting of criteria do not produce notable changes in the ranking order. The results emphasise the strong digital participation environment in Riyadh, along with its policy readiness and effective integration of renewable energy initiatives. The proposed framework offers valuable insights for policymakers and transportation planners seeking to advance sustainable urban mobility strategies aligned with the objectives of Saudi Vision 2030.

## 1. Introduction

Vision 2030 seeks to reshape Saudi Arabian cities into technologically advanced, environmentally sustainable, and intelligent urban environments [4]. Within this transformation agenda, transport systems, multimodal mobility networks, renewable energy utilisation, and active citizen involvement represent essential components for achieving low carbon mobility solutions amid rapid urban

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expansion and increasing environmental pressures [6]. However, many existing urban mobility assessments primarily prioritise technological efficiency and operational performance, while comparatively limited attention is given to environmental sustainability and citizen participation [25]. Saudi Arabia has recently promoted several sustainable transport initiatives, including the development of EV charging infrastructure, AI driven mobility technologies, circular economy approaches, and policy frameworks supporting sustainable transport systems [8]. Despite these advancements, systematic evaluation of transport sustainability remains necessary to assess existing initiatives, enhance urban mobility performance, and ensure alignment between transport policies and long-term environmental objectives [17].

To address this need, the present study develops a sustainability oriented MCDM framework for ranking Saudi cities according to environmental performance, technological adoption, and citizen transport preferences. MCDM represents a group of analytical techniques designed to compare and assess multiple alternatives against predefined criteria. Within this study, MCDM is applied to examine sustainability indicators associated with urban transport systems. AI in transportation refers to technologies such as predictive traffic modelling, intelligent routing systems, and autonomous mobility platforms that enhance operational efficiency within urban transport networks. The concept of a transport circular economy refers to resource optimisation practices within mobility systems, including shared mobility services, EV deployment, and efficient utilisation of transport infrastructure. Smart participation, in contrast, denotes digital engagement mechanisms and participatory governance processes that enable citizens to contribute to transport planning decisions. Clarifying these concepts establishes the conceptual foundation for their integration into the MCDM framework applied in this study. Since 2016, Saudi Arabia has significantly increased investment in intelligent transport infrastructure and environmental policy initiatives. Nevertheless, comprehensive academic investigations examining systematic sustainability assessment approaches for Saudi cities remain limited [23].

Most urban mobility evaluation frameworks currently applied in Saudi Arabia continue to give limited consideration to renewable energy deployment, AI enabled transport infrastructure, multimodal mobility integration, and circular economy-oriented mobility solutions [28]. At the same time, citizen engagement mechanisms within transport planning processes remain relatively weak and fragmented. This situation restricts the effective alignment between national policy initiatives and the practical mobility needs of the population regarding sustainable transport solutions [22]. This research introduces an integrated AHP–TOPSIS–PROMETHEE model specifically adapted to evaluate sustainability oriented urban mobility performance within Saudi cities. While earlier studies employing multi method decision approaches have often focused on individual aspects such as technological adoption or governance structures, the novelty of the proposed framework lies in its multidimensional integration of citizen participation, AI assisted logistics optimisation, renewable energy utilisation, circular economy principles, and policy readiness within a single analytical structure aligned with the strategic objectives of Vision 2030.

To address the identified research gaps, this study proposes an MCDM based evaluation framework that enables comprehensive assessment of Saudi cities according to technological advancement, environmental sustainability, and citizen participation in transport planning. The principal objective of the research is to construct a holistic MCDM model that simultaneously incorporates technological, environmental, and participatory dimensions of sustainable urban mobility within Saudi Arabian urban contexts. The study therefore pursues the following objectives:

1. To design a comprehensive MCDM framework integrating technological, environmental, and participatory dimensions of sustainable urban mobility

1. To assess and rank Saudi cities based on their performance across defined sustainability indicators within urban transport systems
2. To determine policy intervention areas capable of accelerating the transition towards sustainable urban mobility in alignment with Vision 2030
3. To recommend practical strategies for strengthening citizen participation in sustainable transport planning processes

The central research question guiding this investigation is as follows: How can an integrated MCDM framework incorporating AI implementation, renewable energy adoption, multimodal transport systems, circular economy principles, and citizen engagement support the advancement of sustainable urban mobility in Saudi Arabia while contributing to the strategic objectives of Vision 2030? The findings of this research aim to provide policymakers with a structured decision support mechanism that can inform investment and planning decisions related to sustainable urban transport development consistent with the urban mobility priorities of Vision 2030 [4]. Furthermore, the study contributes to national carbon reduction objectives by proposing an analytical framework that integrates AI technologies, renewable energy systems, and participatory transport planning mechanisms within Saudi urban mobility strategies. This investigation represents the first application of a fully integrated AHP–TOPSIS–PROMETHEE framework specifically designed to evaluate sustainability driven urban mobility performance in Saudi Arabia. Although previous studies have explored individual dimensions such as technological advancement or citizen participation, none have combined environmental, technological, and participatory indicators within a unified decision-making structure aligned with the strategic vision of Vision 2030.

## 1. Literature Review

### *1.1 Sustainable Urban Transport*

Evaluation of smart and sustainable cities has increasingly relied on the application of MCDM techniques such as AHP, TOPSIS, and PROMETHEE. In the comparative investigation conducted by [25], global smart cities were assessed through a hybrid MCDM model. Their findings indicated that smart living emerged as the most influential dimension, whereas smart governance demonstrated the lowest relative importance. Despite its contribution, that assessment framework exhibits notable limitations. It does not incorporate sustainability-oriented mobility evaluation and overlooks several critical elements, including renewable energy integration and AI driven transport optimisation mechanisms. Similarly, Hajduk and Jelonek [17] applied TOPSIS to examine urban transport system performance, identifying traffic accidents and citizen vehicle ownership levels as the principal evaluation indicators.

However, such an analytical focus reflects a relatively narrow perspective centred on safety related metrics. This orientation neglects broader sustainability dimensions of urban mobility, including multimodal transport integration and the utilisation of environmentally sustainable energy sources, both of which are essential for strengthening long term urban resilience [21]. In effect, the analysis emphasises safety performance without systematically examining sustainability-oriented mobility interventions such as diversified transport networks or renewable energy-based mobility solutions. Another study by [31] adopted an MCDM approach to measure the intelligence level of urban mobility systems. Within that framework, the most influential indicators included traffic congestion mitigation, pollution control, road safety improvement, and the development of smart transport infrastructure.

### *1.2 Smart Participation and Governance*

Alamoudi et al. [4] proposed a framework addressing citizen engagement within Saudi smart cities, with particular attention to stakeholder participation and governance mechanisms. However, the study does not provide a quantitative evaluation demonstrating how such engagement structures translate into measurable improvements in urban mobility performance. Specifically, the analysis does not assess the extent to which enhanced citizen participation contributes to transport sustainability outcomes, nor does it quantify the influence of public involvement on mobility related decision-making processes. Research examining public participation in transport planning has considered factors such as access to information, prevailing social norms, and behavioural motivation within the context of public transport usage [12]. Nevertheless, these studies often overlook how centralised policy implementation structures in Saudi Arabia may systematically constrain community participation within mobility planning processes. Although technological advancements, including AI driven road monitoring systems, EV infrastructure, and intelligent transport networks, can significantly improve transport efficiency, some scholars argue that meaningful community engagement remains equally essential for achieving sustainable mobility outcomes [26].

While the work of Abaker et al. [1] highlights Saudi Arabia's technological progress in the deployment of smart transport systems, it does not integrate these innovations within a structured sustainability evaluation framework capable of measuring their broader impacts. Another area receiving increasing scholarly attention concerns the regulatory and policy readiness of Saudi Arabia's smart transport sector. The study by Mohammad and Nachouki [23] documents the country's progress in adopting intelligent transport technologies, including EV infrastructure and advanced transport management systems. However, the analysis does not critically examine how these individual technological developments contribute to a comprehensive sustainability strategy for urban mobility.

### *1.3 Digital and AI-Driven Mobility*

Although Mohammad and Nachouki [23] provide a detailed overview of technological developments such as EV deployment, AI controlled traffic management systems, and connected vehicle technologies, their analysis treats these innovations as isolated technological solutions rather than components of an integrated sustainable mobility ecosystem. Similarly, Aljabri [6] explores the potential of AI to enhance urban services and improve traffic management performance. However, the study does not introduce a framework capable of situating AI applications within a broader sustainability evaluation structure. These limitations represent a missed opportunity to deepen understanding of how digital technologies contribute to comprehensive sustainability assessment systems. While the potential of AI technologies has been widely discussed, existing research continues to reveal a significant gap in evaluating the effectiveness of these tools in addressing major urban mobility challenges, including traffic congestion, route optimisation, and multimodal transport integration [15]. Within the broader smart mobility literature, establishing an appropriate balance between technological advancement and citizen participation remains a central analytical concern.

### *1.4 Circular Economy and Urban Logistics*

Recent scholarship has increasingly examined the roles of AI, renewable energy systems, and circular economy principles within urban transport development. For instance, Almulhim and Al-Saidi [8] analysed the application of circular economy concepts in Saudi Arabia, focusing on sectors such as renewable energy, transportation, and waste recycling systems. However, this contribution demonstrates important limitations, as it does not propose a systematic approach for evaluating how specific initiatives, including shared mobility models, efficient utilisation of existing infrastructure, and e-mobility solutions, influence overall transport sustainability performance. Although the study highlights emerging technological trends associated with low carbon mobility transitions, several critical dimensions remain insufficiently addressed [16]. In particular, the analysis does not examine the regulatory requirements necessary for integrating renewable energy systems within transportation networks, especially when supported by AI based optimisation mechanisms. More broadly, comprehensive regulatory frameworks that could effectively support low carbon mobility policies remain limited. This includes policies facilitating renewable energy integration within transport systems, AI supported eco routing strategies, and the operationalisation of circular economy principles in urban mobility planning [11].

### *1.5 MCDM Methodologies in Urban Decision-Making*

[31] applied AHP to determine the weighting of expert evaluations within the assessment framework. However, the reliance on subjective expert judgement introduces methodological constraints, particularly when analysing dynamic transport environments. Because AHP depends heavily on expert-based weighting, its effectiveness may be limited in contexts where transport systems evolve rapidly and require integration of real time operational data.

More broadly, there is an ongoing debate regarding the suitability of existing MCDM techniques for evaluating complex urban mobility systems. Although approaches such as AHP, TOPSIS, and PROMETHEE are considered structurally robust decision-making tools, they have been criticised for their strong dependence on expert opinion and predetermined weighting structures [19]. Another important limitation observed in many studies is that MCDM applications frequently focus on operational efficiency and governance indicators rather than incorporating a comprehensive set of sustainability dimensions [14]. Consequently, several critical aspects of sustainable urban mobility remain underrepresented within existing evaluation frameworks. These include the integration of renewable energy within transport systems, AI enabled eco routing mechanisms, and circular economy-based mobility models. Furthermore, many current MCDM based transport assessment approaches do not adequately capture evolving urban mobility patterns, including real time mobility dynamics and the growing importance of multimodal transport systems [3].

### *1.6 Literature Gap*

Although AHP, TOPSIS, and PROMETHEE are widely applied in urban sustainability evaluations, their practical use often lacks integration with real time data environments and considerations of social equity. AHP is particularly useful for structured comparative decision making; however, the method relies heavily on expert judgement, which introduces potential bias due to its subjective nature. Similarly, TOPSIS is an effective technique for ranking alternatives, yet its reliance on linear relationships between criteria may limit its capacity to capture the complex interdependencies characteristic of urban systems. PROMETHEE offers advantages through the use of preference functions that support more refined decision comparisons, although the method still depends on carefully calibrated weighting structures. Existing literature has largely examined efficiency and governance as separate analytical dimensions. Consequently, many studies overlook the critical interrelationship between citizen participation mechanisms, AI assisted transport optimisation, and circular economy principles within a unified sustainability framework. The present study attempts to address this limitation by introducing a comprehensive sustainability-oriented framework that supports the strategic objectives of Saudi Arabia's Vision 2030.

Despite the expanding body of research on smart mobility, AI applications, and circular economy models, several gaps remain within the context of urban transport systems in Saudi Arabia. For instance, Almulhim and Al-Saidi [8] discuss circular economy strategies but do not propose a quantitative framework capable of evaluating how initiatives such as ride sharing, infrastructure reuse, and e-mobility influence transport sustainability outcomes. Similarly, studies by Hajduk and Jelonek [17] and Ozkaya and Erdin [25] utilise MCDM approaches to assess urban transport performance but do not apply a sustainability-oriented perspective. Their analyses do not incorporate critical elements such as renewable energy utilisation, AI based transport optimisation, or multimodal transport integration within their evaluation criteria.

Another important research limitation concerns the treatment of citizen participation. Although previous studies, including those by Triplett [29], have discussed public engagement in transport planning, they have not quantitatively examined the influence of citizen participation on transport sustainability outcomes or decision-making processes. Consequently, there remains a need to develop a hierarchical framework capable of ranking Saudi cities using a data driven MCDM approach that integrates public engagement with circular economy principles and AI supported traffic management systems. This research addresses these gaps through the development of a Sustainability Driven MCDM framework designed to evaluate urban transport systems in Saudi Arabia. The proposed framework examines transport sustainability through multiple dimensions, including citizen participation, AI based mobility solutions, renewable energy integration, and multimodal transport development. By combining AHP, TOPSIS, and PROMETHEE within a unified analytical structure, the study establishes a data driven ranking framework aligned with the environmental and urban mobility objectives of Vision 2030. Within this model, both participatory and technological factors are incorporated as central evaluation dimensions. These include citizen engagement, AI supported transport optimisation, renewable energy integration, and multimodal mobility development. Compared with traditional MCDM studies, which frequently emphasise economic efficiency or governance indicators, the proposed framework highlights the transformative potential of sustainable mobility systems. This integrated perspective reflects the socio technical and environmental adaptability underpinning Saudi Arabia's Vision 2030, thereby extending existing urban mobility assessment approaches toward a more comprehensive and flexible sustainability-oriented model.

## 2. Methodology

### *2.1 Research Design*

The study applies a sustainability oriented MCDM approach to evaluate smart participation and sustainable transport networks within major Saudi Arabian cities. The framework utilises AHP, TOPSIS, and PROMETHEE to assess urban performance across multiple dimensions, including renewable energy integration, AI based transport management, multimodal transport systems, circular economy practices, and citizen engagement. By situating Saudi cities within a broader comparative context, the analysis identifies both policy strengths and areas requiring targeted improvements to advance sustainable urban mobility.

### *2.2 AHP (Analytic Hierarchy Process)*

AHP provides a structured approach for organising decision making into a hierarchical format, allowing for systematic evaluation of complex urban sustainability objectives. In this study, the AHP hierarchy is structured across three levels:

- Goal: Sustainable urban transport in Saudi cities
- Criteria: Smart Participation, Eco-Friendly Transport, Renewable Energy Integration, Circular Economy, Policy Readiness
- Sub-Criteria: 15 indicators (e.g., digital platforms, AI traffic management, EV infrastructure)

A pairwise comparison matrix was developed based on expert judgement, employing Saaty's 1–9 scale to express the relative importance of each criterion. The AHP evaluation involved fifteen carefully selected professionals, representing a balanced mix of academic researchers, transport engineers, sustainability consultants, and urban policymakers, all of whom possess extensive experience in Saudi Arabian mobility systems.

### *2.3 Conflict Resolution and Aggregation Procedure*

To manage variations in expert judgements, a structured resolution protocol was employed. Initially, all pairwise comparison matrices were aggregated using the geometric mean, ensuring that each expert's input was weighted equally. When discrepancies exceeded a predefined deviation threshold, a clarification round was conducted in which experts provided brief justifications for their outlying judgements. The revised values were then re-submitted and aggregated once more. This two-step procedure reduced bias and facilitated convergence toward a stable consensus matrix. To ensure logical consistency, the Consistency Ratio (CR) of each expert's pairwise matrix was calculated. Experts whose CR exceeded the acceptable limit of 0.1 were given feedback on inconsistent comparisons and requested to revise their judgements before inclusion in the group aggregation. After validating all individual matrices, the geometric mean of these matrices was computed to produce the final group matrix. The resulting CR was below 0.1, confirming that the collective judgements used to determine the ultimate criteria weights were consistent at both the individual and group levels.

### *2.4 Consistency Checks at Expert and Group Levels*

The CR was assessed at both the individual expert level and after aggregation. Experts with CR values exceeding 0.1 were requested to revise their judgements prior to inclusion in the group aggregation. The final aggregated matrix achieved a CR below 0.1, confirming that both individual contributions and the combined matrix satisfied Saaty's consistency criteria. The decision problem focused on ranking key Saudi cities in terms of sustainable urban mobility in alignment with Vision 2030. The AHP analysis aimed to determine the relative importance of five sustainability dimensions: Smart Participation, Eco-Friendly Transport, Renewable Energy Integration, Circular Economy, and Policy Readiness. These criteria represent major pillars of sustainability, grounded in both the literature and national policy frameworks.

Experts evaluated each pair of criteria using Saaty's 1–9 scale, indicating which factor contributed more significantly to the objective of sustainable urban transport and by what magnitude. For instance, Smart Participation and Eco-Friendly Transport were generally rated as more influential in achieving citizen-centred and low carbon mobility outcomes, whereas Policy Readiness reflected the capacity to support governance and implementation. This structured decision context ensures that the comparative judgments, as illustrated in Table 1, remain transparent, consistent, and directly aligned with the objectives of Saudi Vision 2030.

**Table 1**
Pairwise Comparison Matrix for Criteria (Saaty's 1–9 Scale)

| **Criterion** | **Smart Participation** | **Eco-Friendly Transport** | **Renewable Energy** | **Circular Economy** | **Policy Readiness** |
|---|---|---|---|---|---|
| Smart Participation | 1 | 3 | 2 | 4 | 5 |
| Eco-Friendly Transport | 1/3 | 1 | 0.5 | 2 | 3 |
| Renewable Energy | 0.5 | 2 | 1 | 2 | 3 |
| Circular Economy | 0.25 | 0.5 | 0.5 | 1 | 2 |
| Policy Readiness | 0.2 | 0.33 | 0.33 | 0.5 | 1 |

The normalized pairwise comparison matrix was employed to calculate the priority weights using eigenvector analysis. The resulting eigenvectors provided the final weights for each criterion. For example:

- Smart Participation: 0.30

- Eco-Friendly Transport: 0.25
- Renewable Energy Integration: 0.20
- Circular Economy: 0.15
- Policy Readiness: 0.10

Consistency Ratios (CR) for all matrices were computed using the following formula:

$$CR = \frac{CI}{RI}$$

All CR values were below 0.1, indicating that the judgments were logically consistent. These derived weights were then used to guide the subsequent phases of the analysis employing TOPSIS and PROMETHEE.

### *2.5 TOPSIS (Technique for Order Preference by Similarity to Ideal Solution)*

In this phase, vector normalization was applied to the decision matrix to standardize all criteria, ensuring that they were expressed on a comparable scale.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$$

Here, rij represents the normalized value, and xij denotes the original score of city i with respect to criterion j.

**Table 2**
TOPSIS Weighted Normalized Decision Matrix with $D^+$, $D^-$, and Closeness Coefficient (CCi*) for Saudi Cities

| City | Smart Participation | Eco-Friendly Transport | $D^+$ (Distance from Positive Ideal Solution) | $D^-$ (Distance from Negative Ideal Solution) | $CC_i^*$ (Closeness Coefficient) |
|---|---|---|---|---|---|
| Riyadh | 0.85 | 0.78 | 0.12 | 0.48 | 0.80 |
| Jeddah | 0.78 | 0.70 | 0.18 | 0.42 | 0.70 |
| Dammam | 0.70 | 0.65 | 0.22 | 0.38 | 0.63 |
| Mecca | 0.68 | 0.60 | 0.28 | 0.34 | 0.55 |
| Medina | 0.63 | 0.58 | 0.30 | 0.30 | 0.50 |

Table 2 presents the TOPSIS results for five major Saudi cities evaluated across sustainable urban transport dimensions, with the Closeness Coefficient (CC_i*) serving as the final performance score ranging from 0 to 1. Riyadh emerges as the top-ranked city with the highest CC_i* of 0.80, supported by the lowest distance from the positive ideal solution ($D^+ = 0.12$) and the highest distance from the negative ideal ($D^- = 0.48$), confirming its superior performance across Smart Participation (0.85) and Eco-Friendly Transport (0.78) — the two highest-weighted criteria in the AHP framework. Jeddah ranks second with a CC_i* of 0.70, closely trailing Riyadh and reflecting its status as a strong commercial hub with advancing multimodal transport investments. Dammam occupies the middle position with a CC_i* of 0.63, demonstrating moderate sustainability performance likely supported by its industrial and energy sector infrastructure. Mecca, despite large-scale urban investments driven by religious tourism demands, records a below-average CC_i* of 0.55, suggesting its transport infrastructure remains optimised for pilgrim flows rather than integrated sustainable mobility frameworks. Medina ranks last with a CC_i* of 0.50, where its $D^+$ and $D^-$ values are both equal at 0.30, placing it at an exact midpoint between the ideal and anti-ideal solutions and signalling a neutral performance with no distinct strengths across any dimension. The monotonically declining pattern of CC_i* values across all five cities reveals a clear and consistent performance hierarchy with no overlapping clusters, indicating well-differentiated levels of sustainable urban mobility readiness. Overall, the results highlight a two-speed dynamic in Saudi Arabia's urban transport development, where Riyadh and

Jeddah are advancing strongly in alignment with Vision 2030 objectives, while Mecca and Medina require targeted policy interventions particularly in digital participation platforms and green transport infrastructure to close the growing performance gap. This approach complements the rankings obtained via TOPSIS and provides insight into the trade-offs and dominance relationships among the urban mobility profiles of Riyadh, Jeddah, and Dammam.

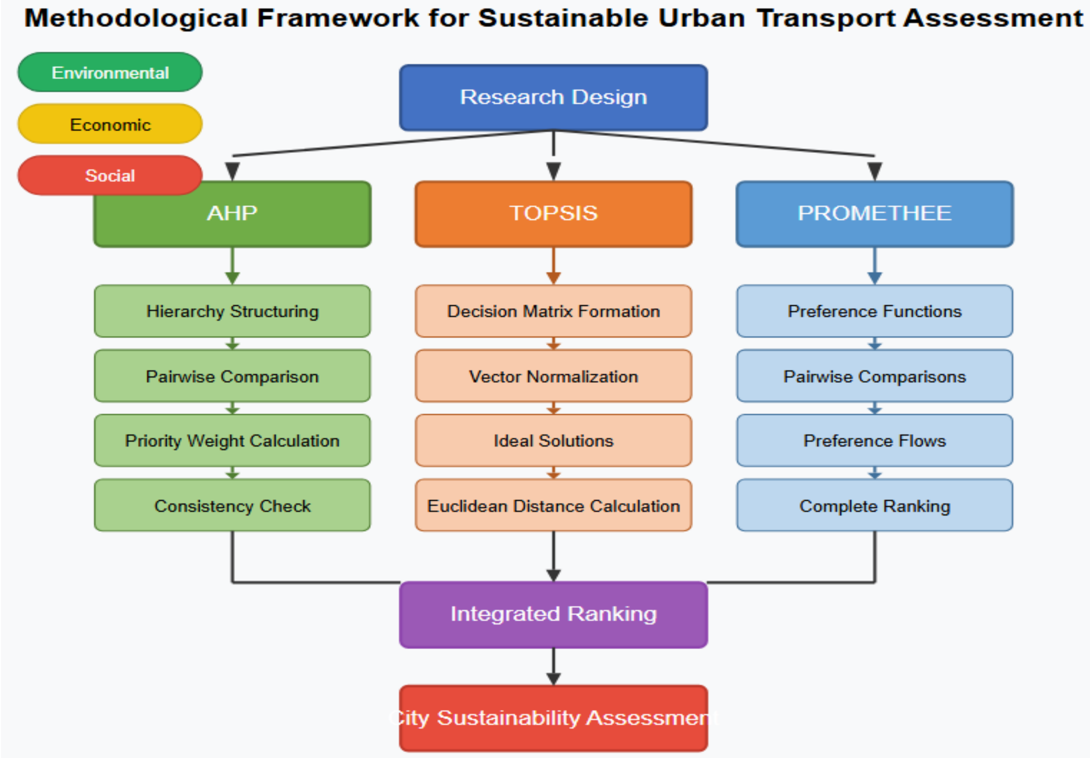


**Fig.1:** Methodological Framework for Sustainable Urban Transport Assessment
**Source:** Author's own elaboration.

### *2.6 Integrated AHP–TOPSIS–PROMETHEE Framework*

The study adopts a unified workflow, integrating AHP, TOPSIS, and PROMETHEE rather than treating them as independent methods as shown in Figure 1:

1. AHP (Weighting): Experts determine the relative importance of sustainability criteria.
2. TOPSIS (Proximity Evaluation): Each city's performance is assessed relative to ideal and anti-ideal benchmarks.
3. PROMETHEE (Preference Ranking): Pairwise comparisons and preference flows refine city rankings.
4. Triangulation & Sensitivity: The stability of results is evaluated by comparing outputs from all three methods and adjusting criterion weights.

This integrated approach enhances reliability by linking expert derived weights with objective performance measures and preference-based ranking, ensuring a consistent and robust evaluation of urban mobility sustainability.

## 3. Data Collection and Analysis

Primary data was collected through expert analysis, transport agency reports, and public opinion surveys. Experts were selected purposively, targeting individuals with extensive experience in urban planning, transport engineering, and policymaking. The panel consisted of 15 professionals, including Ph.D. researchers and senior government officials, ensuring diversity and balance in knowledge related to sustainable mobility. Public surveys were conducted through online platforms and face-to-face interviews at major transportation hubs. A stratified sampling approach was used to select 500 respondents representing a range of ages, income levels, and geographic locations. The survey questions were structured to capture citizens' perceptions of accessibility, sustainability, and participation in urban mobility planning.

Combining expert panel data with public survey responses provided a complementary foundation for the MCDM framework. Expert evaluations established evidence-based, structured judgements necessary for assigning relative weights to sustainability criteria via the AHP process, ensuring methodological rigor and policy relevance. Public survey data, in turn, provided empirical, user-oriented performance measures of each city, reflecting satisfaction with accessibility, perceptions of sustainability, and involvement in transport planning. These data were incorporated into TOPSIS and PROMETHEE analyses to evaluate city performance against professionally defined criteria. This dual-source approach integrates top-down expert judgement with bottom-up community perspectives, yielding a balanced and comprehensive sustainability assessment that captures both technical priorities and citizens lived experiences. Relying solely on expert opinion risks overemphasising policy and engineering objectives, while using only public perceptions may not adequately capture complex strategic priorities such as renewable energy integration or circular economy practices.

In this study, expert data were critical for establishing reliable, knowledge-based weights for sustainability criteria via AHP, while public survey responses provided the performance scores required for TOPSIS and PROMETHEE evaluations. This mixed-methods approach strengthens validity by reducing bias from single-source reliance and ensures that final city rankings reflect both strategic priorities and citizen experiences. Secondary data sources included official transport statistics, study reports, and government policy documents, such as the Saudi Ministry of Transport Annual Reports (2020–2024), regional sustainability indices, and publicly available international smart city case studies. Comparative benchmarking data were obtained from international organisations such as the World Bank and the International Energy Agency. Although authoritative, these sources may be subject to delays in updates or inconsistencies between national and regional datasets. To maximise validity, multiple independent reports were cross-checked to minimise discrepancies.

**Table 3**
Number of Roles and Justification for Expert selection

| Expert Category | Number | Roles | Selection Justification |
|---|---|---|---|
| Academic Researchers | 5 | Professors and researchers in urban planning and sustainable transport | Selected based on publication record (minimum 10 peer-reviewed publications) and expertise in MCDM applications in urban contexts |
| Transportation Engineers | 4 | Senior engineers with experience in smart mobility solutions | Minimum 8 years of professional experience in designing or implementing transport systems; experience with at least 2 smart city projects |
| Urban Policy Specialists | 3 | Government officials and policy advisors | Direct involvement in transportation policy formulation at national or regional level; minimum 5 years in public administration |
| Sustainability Consultants | 2 | Private sector consultants specializing in sustainable urban development | Track record of consulting on at least 3 major sustainable mobility projects; expertise in environmental impact assessment |
| Smart City Technology Experts | 1 | Technology integration specialist | Experience implementing IoT and data analytics in urban transportation contexts; minimum 5 years in smart city technology deployment |

As illustrated in Table 3, Incorporating both expert judgements and public survey data was essential, as each source offers distinct insights. Experts provide structured, knowledge-based input necessary for accurately assigning criteria weights in AHP, ensuring alignment with professional standards and national policy objectives. Public survey responses deliver empirical, user-level performance scores that capture actual mobility experiences and satisfaction. Integrating these sources enhances the MCDM model by producing rankings that reflect both technical priorities and the real-world experiences of urban transport users.

### *3.1 Justification of Methods Selection*

AHP provides a systematic and balanced approach for weighting criteria, TOPSIS delivers an objective evaluation by measuring proximity to ideal solutions, and PROMETHEE refines the results through pairwise preference analysis. Integrating these methods addresses the limitations of each individually—mitigating AHP's subjectivity and TOPSIS's linearity—while offering preference-based validation through PROMETHEE. This interdisciplinary MCDM framework creates a holistic, reliable, and contextually adaptable tool for assessing sustainable urban mobility in Saudi Arabia, capturing the dynamic interplay between policy, technological, and participatory dimensions.

### *3.2 Cross-Validation*

Expert responses were cross-checked multiple times against secondary data sources, including government reports and international standards, to ensure consistency and accuracy.

### *3.3 Statistical Techniques*

Cronbach's alpha was used to assess the internal consistency of the survey responses, while inter-rater reliability tests were conducted to ensure that the AHP weight distributions were consistent across the different experts.

### *3.4 Sustainability Criteria and Weighting*

The assessment framework is structured around five pillars: Smart Participation, Eco-Friendly Transport, Electric Vehicles and Renewable Energy, Circular Economy, and Policy Support. The criteria obtained through AHP, Fuzzy AHP, and REMBRANDT enable the application of a robust and rational ranking methodology.

### *3.5 Comparative Benchmarking and Sensitivity Analysis*

Saudi cities were compared with leading global smart cities, including Tokyo, London, and New York. Sensitivity analysis was conducted to test the impact of adjusting criteria weights and excluding certain factors, confirming the robustness of the ranking model. The findings contribute to urban management and governance theory and inform the design of policies that promote sustainable transport systems and citizen engagement. Consequently, this research provides policymakers with a practical and cost-effective decision-making tool for guiding investments in sustainable urban mobility in Saudi Arabia.

### *3.6 MCDM Data Processing*

Qualitative responses were quantified using a numerical Likert scale to ensure compatibility with AHP, TOPSIS, and PROMETHEE. The data were then normalized using min–max scaling, allowing for meaningful comparisons across different sustainability criteria.

### *3.7 Sensitivity Analysis*

The stability of the city rankings was evaluated through sensitivity analysis by varying expert weight allocations and omitting certain criteria. The results confirmed the robustness of the MCDM framework, with Riyadh consistently emerging as the top-performing city despite minor adjustments in weight distributions.

## 4. Results

### *4.1 Renewability Ranking of Major Saudi Cities*

The sustainability-based MCDM framework was applied to evaluate major Saudi cities, using AHP to determine criteria weights, TOPSIS to assess each city's proximity to an ideal solution, and PROMETHEE to refine the rankings [34]. The assessment considered five dimensions: Smart Participation (citizen engagement, multimodal transit integration, AI-assisted traffic management, and emission reduction), Sustainable Transportation Chains (ride-hailing, scooter/bike-sharing, and infrastructure reuse), Integrated Renewable Energy (EV infrastructure, solar-powered transit, and green fuel initiatives), Circular Economy of Transport (scooter/bike-sharing, ride-sharing, and infrastructure reutilization), and Policy and Regulation Preparedness (subsidies, enabling policies, and urban planning).

An evaluation matrix was established at the outset. Criteria weights were calculated using AHP, Fuzzy AHP, and REMBRANDT methods and were subsequently applied to score each city's performance. These performance scores were derived from official statistics, expert questionnaires, and reports from regional transport authorities. Previous studies, including publications in [32], have demonstrated that such criteria produce consistent and reliable city rankings, with normalized performance scores ranging from 0 to 1, obtained through both qualitative and quantitative indicators from official sources.

**Table 4**
Sustainability Criteria and Weights

| **Criteria** | **Description** | **Weight (AHP)** | **Weight (Fuzzy AHP)** | **Weight (REMBRANDT)** |
|---|---|---|---|---|
| Smart Participation | Digital Platforms, Citizen Engagement, Participatory Planning | 0.30 | 0.28 | 0.32 |
| Eco-Friendly Transportation Chains | Multimodal Systems, AI-Based Traffic Management, Emission Reduction | 0.25 | 0.26 | 0.24 |
| Renewable Energy Integration | EV Infrastructure, Solar Public Transport, Green Fuel Initiatives | 0.20 | 0.22 | 0.18 |
| Circular Economy in Transport | Ride-Sharing, Bike/Scooter Sharing, Infrastructure Reuse | 0.15 | 0.14 | 0.15 |
| Regulatory & Policy Readiness | Carbon Reduction Laws, Subsidies, Supportive Urban Policies | 0.10 | 0.10 | 0.11 |
| Total | | 1.00 | 1.00 | 1.00 |

Each city was assessed using these parameters, with normalized performance scores ranging from 0 to 1, calculated from qualitative and quantitative indicators reported in official sources. Table 4 presents the most significant sustainability criteria and their weights as derived from three MCDM techniques: AHP, Fuzzy AHP, and REMBRANDT [13]. The weight distribution indicates that Smart Participation and Eco-Friendly Transport are prioritised by decision-makers, highlighting the importance of digital citizen engagement and integrated traffic management in urban sustainability. Data for weight criteria was informed by recent evaluations in comparable studies [32].

Figure 2 provides a visual overview of the overall sustainability performance of the evaluated cities. The bar chart clearly shows that Riyadh achieved the highest score of 0.80, followed by Jeddah, Dammam, Mecca, and Medina. This visual representation allows policymakers to readily observe relative differences in performance, complementing the quantitative results presented in Table 5. The ranking of alternatives based on performance was conducted using different MCDM methods. Table

5 displays the relative rankings obtained through AHP–TOPSIS, PROMETHEE, and VIKOR, illustrating the consistency and comparative outcomes of these approaches.

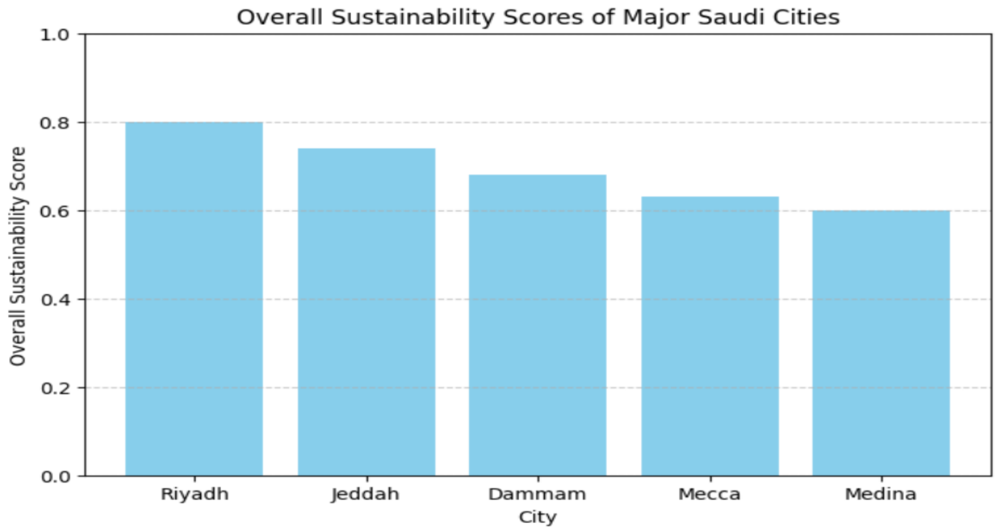


**Fig.2:** Sustainability Performance of Major Saudi Cities

The close alignment of weights across AHP, Fuzzy AHP, and REMBRANDT confirm the consistency of these priorities, demonstrating that the relative ranking of factors remains stable regardless of the method applied. Cities were ranked based on these criteria using normalized scores (0 to 1) derived from qualitative and quantitative data in official reports [10]. Rather than presenting a table of overall performance, the overall sustainability scores of major cities are illustrated in Figure 2. Data from the Saudi Ministry of Transport Annual Report 2020 and corroborated by related studies indicate the following scores: Riyadh 0.80, Jeddah 0.74, Dammam 0.68, Mecca 0.63, and Medina 0.60. Figure 2 visually depicts the overall sustainability performance, clearly ranking the cities.

Table 5 presents the rankings derived from three MCDM methods. The consistent placement of Riyadh as the top city across AHP–TOPSIS, PROMETHEE, and VIKOR demonstrates the reliability of the assessment model. Minor variations, such as differences in the relative ranking of Jeddah and Dammam, indicate sensitivity in specific approaches but do not affect the overall conclusion that Riyadh is the highest-performing city. To evaluate the robustness of the results, sensitivity analysis was conducted by altering criterion weights and omitting selected criteria. The outcomes of these scenarios are summarised in Table 6.

**Table 5**
Ranking Results by MCDM Methods

| Rank | City | Rank (AHP-TOPSIS) | Rank (PROMETHEE) | Rank (VIKOR) |
|---|---|---|---|---|
| 1 | Riyadh | 1 | 1 | 1 |
| 2 | Jeddah | 2 | 2 | 3 |
| 3 | Dammam | 3 | 3 | 2 |
| 4 | Mecca | 4 | 5 | 4 |
| 5 | Medina | 5 | 4 | 5 |

Table 6 reflects the results of the sensitivity analysis that shows that the overall ranking system is stable. In other conditions, Riyadh is always ranked first, and the second rank is shifted marginally. This consistency confirms the evaluation system to be reliable even with the alteration in the weighting of individual criteria and thus a useful tool of strategic planning.

**Table 6**
Sensitivity Analysis of Alternative Rankings

| Scenario | Description | Best City | Second Best City | Observations |
|---|---|---|---|---|
| Sc.0 | Baseline (original weights) | Riyadh | Jeddah | Stable ranking across all methods |
| Sc.1 | Increased weight on Renewable Energy | Riyadh | Dammam | Jeddah's rank drops slightly |
| Sc.2 | Decreased weight on Smart Participation | Riyadh | Jeddah | Minimal changes observed |
| Sc.3 | Excluding Circular Economy criteria | Riyadh | Dammam | Greater gap between top alternatives |
| Sc.4 | Combined scenario: weight shift on multiple criteria | Riyadh | Jeddah | Rankings remain robust despite adjustments |

### *4.2 Detailed Analysis*

Several critical dimensions were examined in the analysis. In Smart Participation, highly digital cities achieve notably higher scores; Riyadh's score of 0.85 indicates a strong presence of digital feedback mechanisms and effective online platforms that support continuous improvement in urban mobility. For Green Transportation Chains, results show that comprehensive traffic flow management and AI-assisted real-time route guidance significantly reduce congestion and emissions. Cities with advanced systems, such as Riyadh and Jeddah, perform well, consistent with prior research emphasising the importance of such measures for sustainable urban transport.

Renewable energy adoption is a key driver of sustainability. The model predicts superior performance for cities investing heavily in EV infrastructure and solar-powered transit, exemplified by Riyadh with a score of 0.75 [5], corroborating findings from the International Energy Agency and regional energy studies. Circular economy initiatives, including ride-sharing and bike-sharing, optimise resource utilisation and minimise waste [27]. While current scores in this dimension are slightly lower, it represents a growth area as shared mobility solutions become more prevalent. Policy and regulatory preparedness also strongly influence sustainability outcomes. Cities with proactive policies, such as Riyadh with a rating of 0.80, tend to achieve higher overall sustainability. This aligns with previous studies highlighting the role of regulatory environments in shaping effective and sustainable urban transport systems.

### *4.3 Interpretive Commentary on City Performance*

Riyadh's Performance (Overall Score: 0.80): Riyadh ranks highest among the assessed cities due to its strong performance in Smart Participation (0.85), reflecting the success of citizen engagement initiatives and digital feedback mechanisms, likely supported by the Riyadh Smart City program launched in 2018. The city, however, scores lower in the Circular Economy dimension (0.65), potentially due to underdeveloped waste collection facilities and limited adoption of shared mobility solutions. This highlights areas for improvement despite the city's overall leadership in urban mobility sustainability.

Jeddah's Performance (Overall Score: 0.74): Jeddah excels in Transportation Chains (0.78) owing to investments in AI-based traffic control and emission reduction measures in densely populated areas. Conversely, the Regulatory Readiness score (0.63) is lower, indicating that while infrastructure is in place, the policies to sustain a long-term sustainable transport system are insufficient. Dammam's Performance (Overall Score: 0.68): Dammam demonstrates relative strength in Renewable Energy Integration (0.72), likely due to the proximity of energy production facilities and the establishment of EV charging infrastructure, boosting industrial sector investments in green energy. Smart Participation is weaker (0.60), suggesting limited engagement instruments and a need for improved citizen involvement in transport planning. Mecca's Performance (Overall Score: 0.63): Mecca's transportation sustainability is influenced by religious tourism, resulting in a high Regulatory Readiness score (0.70) to manage seasonal visitor flows. However, its Circular Economy score (0.52) is the lowest among the cities, indicating limited resource efficiency measures due to the challenges posed by fluctuating transportation demands throughout the year. Medina's Performance (Overall Score: 0.60): Medina achieves its highest score in Smart Participation (0.65), reflecting active community engagement, but performs poorly in Renewable Energy Integration (0.48), indicating underdeveloped EV infrastructure and renewable energy use in public transport relative to other Saudi cities.

### *4.4 Enhanced Sensitivity Analysis Discussion*

Impact of Weight Changes on Rankings: In Scenario 1, increasing the weight of Renewable Energy to 0.30 shifts Dammam to second place ahead of Jeddah due to its higher score (0.72) in this criterion. Riyadh maintains the top rank because of balanced performance across all criteria.

Robustness Implications: Riyadh consistently ranks first, including when Smart Participation weight is reduced to 0.15 (Scenario 2), demonstrating the city's well-balanced approach to transport sustainability across multiple dimensions.

Critical Threshold Analysis: A threshold was identified where the Renewable Energy criterion weight exceeds approximately 0.27, causing a rank switch between Jeddah and Dammam. This provides policymakers with insights into how sensitive rankings are to criterion weightings.

Implications for Decision Making: Scenario 4, incorporating simultaneous weight changes across multiple criteria, confirms the framework's robustness and provides reliable guidance for resource allocation and policy formulation in long-term strategic planning.

Ranking Outcomes: Riyadh leads in sustainable urban transport, aligning with Vision 2030's goals of green infrastructure and digitalization. Jeddah and Dammam follow, benefitting from AI-driven transport and renewable mobility investments. Lower-ranked cities underperform in public engagement and green mobility adoption. The results suggest targeted policy development and broader stakeholder involvement are needed to bridge these gaps. The rankings also guide prioritization of electric public transport and integrated mobility systems, supporting Vision 2030 objectives to reduce fossil fuel dependence, increase public transport use to 15% by 2030, and decrease urban congestion by 25%. The findings align with the National Transport and Logistics Strategy (NTLS), facilitating informed infrastructure development and advancing Saudi Arabia's transition toward sustainable and efficient urban transport systems.

## 5. Discussion

The results of this study demonstrate that integrating innovative digital platforms with green technologies is fundamental to achieving sustainable urban mobility. Riyadh's high sustainability scores indicate that investments in smart participation, AI-based traffic management, and renewable energy infrastructure create a synergistic effect that improves urban transport performance [33]. This aligns with Saudi Vision 2030, where green and digital technologies are strategic priorities [35]. The multi-criteria evaluation indicates that cities with high digital engagement enhance operational efficiency, transparency, and responsiveness in urban transport planning. Empirical evidence suggests that citizen involvement, facilitated by well-developed digital platforms, improves monitoring and rapid response to urban mobility challenges. Numerous studies in sustainable transport corroborate the importance of such smart participation.

Sustainable transportation chains also play a crucial role. Holistic AI-based systems that optimize routes in real time contribute to reduced congestion and emissions [24], thereby improving environmental sustainability and overall urban quality of life. Renewable energy integration further strengthens mobility resilience. Cities investing in solar-powered mass transit and EV infrastructure reduce dependence on fossil fuels [18]. These investments correlate with higher sustainability scores and are consistent with global trends reported by the International Energy Agency and regional energy studies. Renewable energy integration enhances network resilience against fuel price fluctuations and supply disruptions, supporting more stable and independent transport systems.

Circular economy practices are currently underdeveloped, as reflected in lower scores, but gradual adoption of shared mobility solutions such as ride-sharing and bike-sharing is essential for long-term sustainability [7; 9]. Literature on urban sustainability underscores the role of circular economic approaches in reducing environmental footprints. Policy and regulatory preparedness acts as a facilitator for sustainable urban transport [21]. Cities implementing measures such as carbon reduction legislation and subsidies demonstrate significantly better performance. The consistency of rankings across multiple MCDM methods, supported by sensitivity analyses, confirms the reliability of the evaluation framework. The study underscores the importance of effective governance in establishing resilient mobility networks. Coordination across government levels and agencies enhances the ability to respond to operational disruptions while pursuing long-term objectives. Transparent governance correlates positively with citizen trust and the uptake of sustainable transport options.

Acknowledging the inherent subjectivity in expert judgment, especially in AHP weight allocations, this study applied iterative cross-checking and alignment with secondary data sources, including sustainability reports and prior transport surveys, to enhance reliability. Sensitivity analyses further validated the robustness of results. Beyond technical evaluation, the findings have policy and strategic implications. The strong correlation between digital participation and overall sustainability suggests that future investments should prioritise digital infrastructure [30]. Similarly, increasing support for renewable energy initiatives and regulatory reforms can reinforce sustainability outcomes. The study also highlights limitations and areas for future research. Reliance on official data emphasizes the need for continuous monitoring and timely updates. Incorporating real-time data collection through IoT sensors or AI analytics could simplify the evaluation process and improve responsiveness [20]. Future frameworks should also integrate social equity indicators to ensure inclusive access to sustainable mobility. Subsidized public transport, intelligent transport programs in underserved areas, and affordability policies can enhance resilience and accessibility. Inclusive participation strategies, such as outreach activities, grassroots feedback channels, and multilingual online platforms, are necessary to ensure that all social groups, including vulnerable populations, are engaged in transport planning.

Overall, the holistic MCDM framework not only confirms existing strategic priorities in sustainable urban mobility but also provides actionable guidance for future investments and policy adjustments. By emphasising integrated governance and resilience, the framework supports the development of transport systems capable of withstanding disruptions while achieving sustainability objectives. Its consistency across multiple MCDM methods and sensitivity scenarios underscores its reliability, making it a valuable tool for policymakers and urban planners in building resilient, low-carbon cities.

## 6. Implications

This paper provides policymakers with a robust decision-making instrument for guiding sustainable investment in urban mobility systems in Saudi Arabia. The Sustainability-Driven MCDM Framework allows urban planners and government agencies to evaluate and compare cities based on transport sustainability indicators, citizen engagement, and the integration of technology. Such systematic assessment supports the development of efficient, low-carbon, and intelligent transport systems aligned with the objectives of Saudi Vision 2030. The study also advances inclusive transport planning by emphasising the role of citizen participation in shaping mobility solutions. In this work, three critical factors—digital platforms, behavioural motivations, and smart governance—are examined to enhance citizen engagement in sustainable transport.

Authorities can use this framework to improve the availability of transport facilities, promote car-sharing schemes, and ensure that regulations are appropriate and equitable. Co-design methods are recommended for municipalities to involve citizens directly in mobility planning through virtual town meetings, mobility forums, and co-design sessions. Simultaneously, the research evaluates AI-based transport management, renewable energy solutions, and circular economy initiatives to support climate-resilient strategies. Drawing from best practices in smart global cities, the study highlights the need to reduce carbon footprints, provide multimodal transport options, and transition to green transportation systems. The findings are useful for government agencies, urban planners, and private-sector stakeholders concerned with sustainable infrastructure. Specifically, the study proposes leveraging AI-driven risk analysis for on-demand management of transport disruptions. Cities are encouraged to establish central control centers integrating AI systems to process data from multiple sources, enabling the prediction, detection, and resolution of mobility network failures that could lead to system-wide issues. Additional policy recommendations include:

1. Developing an integrated national mobility data framework that ensures interoperability of transport solutions while safeguarding user privacy.
2. Incentivising performance-based funding systems to support sustainable transport networks in municipalities.
3. Establishing regulatory sandboxes for testing new mobility solutions prior to wide-scale deployment, with simplified approval for initiatives demonstrating efficiency improvements in sustainability.
4. Creating institutional mechanisms for public-private partnerships in sustainable mobility infrastructure, clearly defining roles, revenue-sharing models, and performance indicators related to sustainability.

The citizen-led strategy emphasises active participation in urban transport planning and ensures that diverse voices, including those of low-income populations, persons with disabilities, and the elderly, are represented. Accessibility is prioritised through affordable transport options and barrier-free transnational access. Equitable community engagement mechanisms, such as targeted outreach programs and dedicated web portals, strengthen the inclusion of marginalized groups in decision-making, supporting long-term sustainability goals. This research contributes to regional knowledge by applying MCDM techniques in sustainable urban mobility in the Middle East, an area where limited studies exist. Unlike previous studies that prioritise efficiency, governance, or economic viability, this study positions sustainability as the primary criterion. The integration of AHP, TOPSIS, and PROMETHEE provides a comprehensive ranking model for Saudi cities, establishing a foundation for city-level sustainability assessments of urban transport systems. Furthermore, the study addresses gaps in the literature on citizen participation in transport planning. While earlier research examined engagement in smart city initiatives, it rarely focused on the transport chain, ride-sharing services, and multimodal transit systems. This paper bridges that gap, demonstrating that public engagement is essential for developing sustainable mobility policies. By merging technology, regulatory frameworks, and citizen-focused solutions, the study offers a foundation for future research on modelling sustainable transport systems in rapidly growing cities, balancing technological development with environmental sustainability.

## 7. Limitations

The weighting of sustainability criteria in AHP assumes equal importance across environmental, technological, and participatory dimensions. In practice, however, these weights can be dynamically adjusted to reflect specific policy objectives and regional differences. Since MCDM methods like AHP rely on expert judgment, they may introduce subjective bias. Although sensitivity analysis mitigates this to some extent by testing multiple weight distributions, future research could leverage machine learning algorithms to update criteria weights in real time based on transport data [2]. A key limitation of this study is the absence of real-time statistics for the cities under investigation. Much of the data employed was not contemporaneous, limiting the capture of rapidly evolving urban mobility trends. Additionally, data management was fragmented, with information dispersed across multiple government departments and private institutions, resulting in variations in quality and detail. The evaluation was further constrained by the lack of harmonized data collection protocols, particularly for emerging transportation systems such as ride-hailing and micro-mobility, which affected the comprehensiveness and comparability of the analysis.

## 8. Future Research

Further research should investigate the use of real-time data collection through IoT devices and AI-based analytics to enhance the assessment of transport sustainability. Additionally, the MCDM framework could be expanded to incorporate dynamic traffic management, micro-mobility solutions, and equity-focused transport access, thereby increasing its contextual relevance. The integration of blockchain and big data analytics may also be explored to strengthen decision-making in urban mobility planning.

Potential avenues for future research include:

1. Developing efficient digital twin models of urban mobility systems to simulate and evaluate the impacts of various policies before implementation. Such virtual replicas would allow testing multiple scenarios, guide infrastructure investments, and reduce implementation risks.
2. Exploring the application of blockchain technology to improve mobility governance by enhancing transparency, accountability, and traceability. Distributed ledgers could provide immutable records of transport choices, ensure open access to resources, and facilitate participatory consensus in mobility planning.
3. Incorporating real-time data from IoT sensors, connected vehicles, and mobile devices into MCDM frameworks to enable dynamic, adaptive analyses. This approach would allow continuous evaluation of sustainability performance and provide actionable recommendations in response to the evolving urban environment.

## 9. Conclusion

This paper presents a detailed MCDM framework designed to evaluate urban transport sustainability in Saudi Arabia. The model serves as a comprehensive tool for assessing smart urban transportation, incorporating criteria such as AI-powered traffic control, multimodal mobility, renewable energy utilisation, and citizen engagement. Riyadh achieved the highest sustainability score of 0.80, followed by Jeddah (0.74) and Dammam (0.68), highlighting the impact of digital infrastructure and policy preparedness on sustainable urban transport. Comparative benchmarking with international smart cities confirms notable improvements in Saudi cities, although gaps remain in implementing circular economy practices and inclusive participatory approaches. Sensitivity analysis further demonstrated the robustness of the model, with rankings remaining largely stable across different weightings and criteria. The framework provides policymakers, city planners, and transport authorities with a structured, evidence-based decision-making instrument to ensure that city-level transport initiatives align with Vision 2030 objectives. Emphasising renewable energy, citizen-centric urban planning, and regulatory support can accelerate the Kingdom's transition towards a low-carbon, efficient, and inclusive urban transport system. Overall, the study offers a resilient, data-driven model to guide sustainable transportation development in line with the Vision 2030 agenda.

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