Ghaemmaghami N. et al.
March 2027
Urban Economics and Planning
Volume 7, Issue 12

36
Original Article

Received: 2026/07/01
Revised: 2026/07/14
Accepted: 2026/07/16

HOW TO CITE THIS ARTICLE
Ghaemmaghami N. Raissi S. Hosseinzadeh Lotfi F. Shahabi A. Economic-implementation prioritization of sustainable transport policies in Tehran: A scenario-based multi-criteria analysis with a phased policy approach. *Urban Economics and Planning* 7(12):36-58.

DOI: 10.22034/uep.2026.589518.1941

Economic-implementation prioritization of sustainable transport policies in Tehran: A scenario-based multi-criteria analysis with a phased policy approach

Nader Ghaemmaghami Noori[1], Sadigh Raissi[2*], Farhad Hosseinzadeh Lotfi[3], Ali Shahabi[4]

1. Ph.D. Candidate in Industrial Management, UAE Branch, Islamic Azad University, Dubai, United Arab Emirates
2. Professor, Department of Industrial Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran
3. Professor, Department of Mathematics, Science and Research Branch, Islamic Azad University, Tehran, Iran
4. Assistant Professor, Department of Industrial Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran

Abstract

Tehran faces the simultaneous challenges of traffic congestion, chronic air pollution, and severe financial and implementation constraints. Under such conditions, the key policy question is not merely to identify the most effective intervention, but to determine the implementation priority, complementary role, and phased sequencing of policies. To address this question, the present study evaluates 11 policy options, including seven stand-alone policies and four combined packages for the 2024-2030 horizon. The study employs a quantitative, two-stage design. First, the outcomes of the scenarios were extracted from an upstream hybrid simulator based on system dynamics, agent-based modeling, and machine learning; the criteria were then weighted using the CRITIC method, and the options were ranked using TOPSIS. In addition, several policy weighting structures were used to analyze the sensitivity of the results. Ten evaluation criteria were considered, covering three domains: transport effectiveness, pollution and health cost reduction, and financial and implementation feasibility. The findings indicate that the low-risk package (Scenario 8) is the most suitable initial option under balanced weighting. Local fleet emissions reduction (Scenario 6) constitutes the cornerstone of clean-air policy, while time-based travel demand management (Scenario 1) is the best starting point under severe financial constraints. The main innovation of the article lies in providing a practical framework for the economic-implementation prioritization of policies and for designing a phased roadmap for sustainable transport under resource-constrained conditions.

Keywords

Air pollution
multi-criteria decision-making
policy prioritization
sustainable transport
Tehran

* Corresponding Author: raissi@azad.ac.ir

1. Introduction

In recent decades, Tehran has become a clear example of the simultaneous transport, environmental, and fiscal crises confronting urban management. Growth in travel demand, the concentration of administrative and service activities, dependence of a substantial share of daily trips on private cars, an aging vehicle fleet, limited network capacity, and persistent air-pollution pressure have confronted urban authorities with a difficult set of choices. In the sustainable transport literature, this situation is not merely a mobility problem; it is linked to quality of life, health, accessibility, social costs, energy consumption, and the city's fiscal sustainability (Banister, 2008; Goldman & Gorham, 2006; Rupprecht Consult, 2019; United Nations Human Settlements Programme [UN-Habitat], 2022). In Tehran, these interconnections are compounded by budget constraints, institutional coordination challenges, and considerations of accessibility equity and distributional effects, all of which play a decisive role in policy selection and prioritization.

Reducing time lost, decreasing car-oriented travel, increasing the share of public transport, reducing particulate matter, controlling capital and operating costs, and maintaining social acceptability are all desirable policy objectives. Yet few policies can achieve all of these objectives simultaneously, rapidly, and at no cost. The central issue in sustainable transport policy for Tehran is therefore not simply the selection of the "best technical policy." The more important question is which policies are most suitable for initial implementation under fiscal constraints, subsidy pressures, institutional difficulty, social sensitivity, and the urgent need to reduce pollution, and which policies should instead be pursued as complementary measures or made conditional on greater resources and capacity. This issue is particularly important for a city such as Tehran, which faces substantial environmental and public-health costs while also operating under serious constraints on municipal budgets and public transport investment (Ahmadi et al., 2022; Bayat et al., 2020; Jafari Shahrestani et al., 2022).

The international literature indicates that urban transport policies are more sustainable when their direct, indirect, and distributional effects are considered simultaneously. Pricing access to the central area can reduce demand for private-car use; however, if public transport quality and capacity are inadequate, social acceptance may decline, and the expected environmental benefits may not be fully realized (Axsen & Long, 2025; Hosford et al., 2021; Selmoune et al., 2020). Improving public transport service quality can increase the share of collective travel, but it generally requires investment, operating expenditure, and subsidy commitments. Fleet clean-up or renewal is also important for reducing local pollutants. But it is not, by itself, a congestion-reduction policy and will not necessarily ease network pressure without demand management or service improvement. Sustainable transport policies must therefore be compared across multiple dimensions rather than evaluated solely based on a single technical or environmental outcome.

In Tehran, this multidimensionality is also linked to the legal and implementation context. Policies such as controlling vehicle access to the central area, managing curbside parking, improving public transport services, renewing the fleet, reducing vehicle emissions, and supporting public transport fares have featured in urban-management experience or plans. The Clean Air Act and its implementing regulations likewise emphasize control of mobile-source pollution, vehicle inspection, restrictions on aging vehicles, fleet renewal, and expansion of public transport (Clean Air Act of Iran, 2017; National Laws and Regulations Portal, 2021). Assessments of Tehran's transport system have also stressed the need to integrate demand management, stronger public transport, and reformed implementation mechanisms (United Nations Economic and Social Commission for Asia and the Pacific [UNESCAP], 2020). The availability of a set of policy instruments, however, does not itself provide a clear implementation priority. Urban authorities must still determine which intervention can be initiated with lower risk, which option should play a complementary role, and which package depends on greater financial resources and institutional coordination.

Previous studies have examined important parts of this problem. Some have assessed the status and indicators of sustainable transport or developed sustainability evaluation frameworks for Iran and Tehran (Heidarpour & Jaberi, 2022; Norouzi et al., 2023). Others have evaluated a project, intervention, or set of transport alternatives using multi-criteria decision-making methods (Morouji et al., 2011; Shahbazi et al., 2021). Methods such as TOPSIS, VIKOR, and other multi-criteria approaches also have a long record of application to transport alternatives and urban planning (Behzadian et al., 2012; Hwang & Yoon, 1981; Opricovic & Tzeng, 2004; Zavadskas & Turskis, 2011). Nevertheless, much of this research focuses on status assessment, evaluation of a single intervention, or ranking based on relatively static decision matrices. The connection among dynamic scenario outcomes, fiscal and implementation constraints, and the timing and conditions of policy execution therefore remains insufficiently examined.

Accordingly, the precise problem addressed in this study is how to convert scenario-based outcomes of transport policies into an economic-implementation priority under resource constraints. Simulation outputs can indicate how each intervention affects congestion, travel patterns, pollution, and health costs; however, they do not by themselves identify which option is most compatible with Tehran's investment constraints, subsidy commitments, and institutional capacity. The study addresses this gap by jointly evaluating the effectiveness and feasibility of eleven options – seven stand-alone policies and four combined packages – over the 2024–2030 horizon. Scenario values were extracted from the controlled outputs of an upstream hybrid simulator that integrates system dynamics, agent-based modeling, and machine learning, and converted into a ten-criterion decision matrix. The criteria cover transport outcomes, pollution and health cost reduction, and financial and implementation feasibility. Objective criterion weights are derived using CRITIC, the alternatives are ranked using TOPSIS, and the robustness of the results is examined under several weighting structures and sensitivity tests. The article focuses on the post-scenario decision layer; its purpose is therefore not to reproduce the full technical architecture of the simulator, but to transform scenario outputs into information usable by urban decision-makers.

The distinction of the present study lies not merely in the use of a multi-criteria decision method, but in linking dynamic scenario outcomes, fiscal and institutional constraints, and the logic of phased policy implementation. Ranking is used not only to identify the option with the highest score, but also to diagnose the role and implementation conditions of each alternative, thereby distinguishing among a suitable initial action, a complementary policy, a clean-air pillar, and a conditional development package. The main research question is therefore as follows: under the simultaneous conditions of network congestion, air pollution, and fiscal and implementation constraints facing Tehran's urban management, which sustainable transport policies or policy packages are most suitable for initial implementation, and which options should be deferred to later stages or made conditional on the fulfillment of financial and institutional prerequisites?

Following the introduction, the article is organized into five sections. Section two explains the theoretical foundations, empirical studies, and the position of the present research. Section three describes the source of the scenario data, the logic for selecting alternatives and criteria, and the weighting and ranking procedures. Section four reports the ranking results and sensitivity tests. Section five compares the findings with previous studies, explains how Tehran-specific characteristics shape the results, and derives implementation implications. Section six summarizes the principal findings, study limitations, and directions for future research.

2. Theoretical and empirical background

2.1. Theoretical foundations and analytical framework

Sustainable transport is generally founded on three pillars: accessibility, environmental sustainability, and economic efficiency. Its objective is not simply faster movement, but providing safe, affordable, low-emission, and reliable access for citizens and economic activities. Sustainable urban mobility planning guidelines emphasize integration among land use, public transport, demand management, stakeholder participation, accessibility equity, and continuous monitoring (European Commission [EC], 2021; Rupprecht Consult, 2019). The Sustainable Development Agenda and United Nations urban reports likewise regard safe and sustainable access as a component of urban quality of life and resilience (United Nations [UN], 2015; United Nations Department of Economic and Social Affairs, 2019; UN-Habitat, 2022). On this basis, the analytical framework adopted here simultaneously considers three domains: transport efficiency and accessibility, the reduction of environmental and health externalities, and the financial and implementation feasibility of the policy.

The effects of transport policies emerge through different, sometimes conflicting pathways. One policy may reduce congestion but create social pressure; another may reduce pollution while requiring high capital expenditure; and a third may be fiscally light but produce only limited environmental effects. Demand control, pricing, and restrictions on car use can therefore be sustainable and implementable only when social acceptance, the quality and accessibility of alternatives, and the use of policy revenues are addressed simultaneously (Hosford et al., 2021; Selmoune et al., 2020; Small & van Dender, 2007; Vickrey, 1969). This perspective shifts transport policy from selecting a single instrument to designing a set of complementary instruments: restricting private cars without strengthening public transport, or expanding public transport without accounting for funding and operating commitments, may not yield a sustainable outcome.

Air pollution and public health, in turn, connect urban transport to health economics and social costs. PM2.5 is a key indicator of air pollution and health risk, and transport planning can affect urban health by reducing emissions and exposure to pollutants (Nieuwenhuijsen, 2016; World Health Organization, 2021). Globally, demand management, changes in travel behavior, improvement of public transport, and cleaner fleet technologies are regarded as complementary pathways for reducing the climate and pollution impacts of transport (Creutzig et al., 2018; EC, 2020; Intergovernmental Panel on Climate Change, 2022). A reduction in pollutant mass, however, cannot necessarily be treated as an equivalent reduction in all health costs, because the conversion of emission reductions into health benefits depends on exposure patterns, dose-response relationships, and the valuation of disease burden. The present analysis, therefore, includes PM2.5 reduction and reduction in the health-cost index as related but distinct criteria.

These conflicts between objectives and constraints make the research problem a multi-criteria decision. Urban decision-makers face heterogeneous criteria, different preferred directions, and changing policy preferences. The present framework distinguishes between “outcome desirability” and “implementation feasibility.” Transport, pollution, and health criteria indicate the outcomes a policy would produce if implemented, whereas fiscal pressure, capital costs, subsidy requirements, and implementation complexity indicate how compatible its initiation and continuation are with urban-management capacity. Consequently, the policy with the greatest technical impact is not necessarily the most suitable policy to initiate, and a low-cost policy is not necessarily a complete solution.

2.2. Empirical studies

Within the Iranian literature, a group of studies has assessed the status of sustainable transport. Their findings indicate that transport sustainability faced serious challenges during the periods examined and land transport has imposed substantial economic and environmental costs (Heidarpour & Jaberi, 2022). This stream of research clarifies the importance and dimensions of the problem, but largely remains at the diagnostic level and does not directly answer which implementable policy should receive priority under resource constraints. More recent studies have sought to design evaluation models for sustainable urban transport with an emphasis on the Tehran metropolitan region. They identify the dimensions and components of urban transport sustainability and show that sustainable transport in Tehran has an established place in the urban economics and planning literature (Norouzi et al., 2023). Their principal focus, however, is on formulating evaluation models and indicators rather than comparing specific policy scenarios in terms of effects, costs, subsidies, and implementation complexity.

The connection between air pollution and the urban economy has also been prominent in research on Tehran. Estimates of the cost of air-pollution-related deaths show that PM2.5 imposes a heavy health burden and economic cost on the city (Bayat et al., 2020). Social cost-benefit analyses of emissions control for light-duty vehicles likewise demonstrate the importance of intervention in mobile emission sources (Tahamipour Zarandi & Moghise, 2022). These studies provide a strong basis for incorporating health outcomes and social costs into policy evaluation. But they generally do not compare health effects alongside congestion, modal shares, capital costs, subsidies, and implementation difficulties within a single decision framework.

The fiscal sustainability of Tehran Municipality and municipal budget deficits further reinforce the economic context of transport-policy decisions. Available evidence indicates that Tehran Municipality faces fiscal unsustainability in some debt and asset ratios, and that municipal budget deficits are associated with unstable revenue sources (Ahmadi et al., 2022; Jafari Shahrestani et al., 2022). These studies show that fiscal constraints in Tehran are not a peripheral consideration; they can determine the scale and timing of transport-policy implementation. Yet this literature has rarely shown how fiscal constraints can be integrated directly with the transport and environmental outcomes of specific scenarios and converted into implementation priorities.

Research on Tehran’s transport system has addressed congestion pricing, travel behavior, traffic-control zones, pollutant emissions, and clean-air programs. Some studies have examined the effects of Tehran's traffic zones on mobility behavior and changes in pricing policy from the perspective of mode choice (Mamdoohi & Hamrang Ghoortlar, 2021; Salarvandian et al., 2017). They show that pricing and access restrictions can affect private-car use and travel-mode choice, but that outcomes depend on the quality of alternatives, the city's spatial structure, and policy design. The limitation of these studies for the present issue is that they generally focus on a single instrument or behavioral outcome and do not simultaneously examine the roles of fleet-emission reduction, public transport subsidies, capital cost, and implementation capacity in determining policy priority.

Emissions inventory and systems modeling studies have also demonstrated the significance of mobile sources and fleet composition in Tehran's air pollution (Abbasi et al., 2024; Shahbazi et al., 2016, 2019; Tahsiri & Arab, 2023; Vafa-Arani et al., 2014). The studies highlight the importance of controlling emissions from aging fleets, motorcycles, and medium- and heavy-duty vehicles, and provide an empirical basis for fleet clean-up and renewal scenarios. Reducing emission intensity is nevertheless a technological and environmental policy and by itself does not determine the effects on congestion, travel demand, or municipal fiscal pressure. The findings of these studies therefore need to be interpreted alongside research on travel behavior and economic feasibility.

Alongside these strands, system-dynamics simulation and policy-modeling studies provide an important capacity to represent feedbacks, stocks, and delays in transport policies (Haghshenas et al., 2015; Rassafi et al., 2014; Shepherd, 2014; Suryani et al., 2020). Their advantage is that they examine policy outcomes as temporal trajectories within the interrelationships among demand, capacity, congestion, energy, and the environment. Their outputs, however, generally remain at the level of comparing scenario effects and are less often converted into an explicit economic-implementation priority that identifies which policy should be implemented immediately, which should serve as a complement, and which should be conditional on resource availability.

Multi-criteria decision-making methods have likewise been used to convert heterogeneous criteria into interpretable rankings. TOPSIS is based on the distance of alternatives from positive and negative ideal solutions, whereas CRITIC calculates criterion weights from information dispersion and conflict among criteria (Diakoulaki et al., 1995; Hwang & Yoon, 1981). Methodological reviews show that TOPSIS and other multi-criteria methods have been widely applied to transport, environmental, energy, and urban-planning problems (Behzadian et al., 2012; Opricovic & Tzeng, 2004; Zavadskas & Turskis, 2011). In Iran, multi-criteria methods have also been used to evaluate urban transport projects and sustainable transport systems (Morouji et al., 2011; Shahbazi et al., 2021). A limitation of this stream is that many applications focus on infrastructure projects, general indicators, or static decision matrices and judgment-based weights. By contrast, the alternatives in the present study are implementable policies and packages, and their decision-matrix values are extracted from dynamic scenario trajectories.

2.3. Position of the present study

A critical review of the literature reveals four related yet often separate stages in previous studies: diagnosing the state of sustainability, estimating policy outcomes, assessing implementation feasibility, and determining the priority and sequence of action. Indicator-based studies mainly diagnose the state and dimensions of the problem; pollution and health studies demonstrate the importance of social costs and control of mobile sources; travel-behavior and pricing studies examine users' responses to restrictive instruments; and simulation models represent the temporal trajectories of outcomes. Multi-criteria methods also allow the comparison of alternatives. Nevertheless, few studies have linked all four stages in a single framework designed to address Tehran's implementation problem.

The principal gap in the literature is not the absence of studies on policy effects or ranking methods, but the lack of a systematic connection among "scenario effects," "fiscal and institutional constraints," and the "timing and conditions of policy implementation." Many studies identify the most important indicator or the policy most effective for a particular outcome; however, they rarely explain which policy should be initiated first, and which should be deferred until additional prerequisites are met, when urban authorities simultaneously face fiscal pressure, subsidy commitments, investment limits, institutional complexity, and social sensitivity.

The present study addresses this gap at three levels. First, the decision matrix is constructed from scenario trajectories produced by a simulation framework rather than solely from disconnected judgments or static indicators. Second, transport, environmental, and health desirability are evaluated alongside financial and implementation feasibility, without equating technical effectiveness alone with implementation priority. Third, the analytical output is not merely a numerical ranking; it is translated into differentiated policy roles and an implementation sequence: immediate action, balanced initial package, clean-air pillar, complementary lever, and conditional development package. The contribution of the article, therefore, lies in strengthening the link between outcome simulation and economic implementation decisions regarding the order and conditions of sustainable transport policies in Tehran.

3. Research method

3.1. Research design and overall logic

In terms of purpose, this is an applied study; in terms of design, it is quantitative and proceeds in two stages. In the first stage, the outcomes of policy alternatives relative to the baseline pathway were extracted from the upstream simulation framework. In the second stage, these outcomes were organized into a multi-criteria decision matrix to weight and rank the alternatives. The units of analysis were seven stand-alone sustainable transport policies and four combined packages for Tehran, and the objective was to support their economic and implementation prioritization. The article focused on the post-scenario stage: converting scenario outputs into comparable criteria and deriving implementation priorities.

The principal geographical scope was the city of Tehran, and alternatives were ranked to support decision-making at the urban-management level. Due to the concentration of a substantial share of activities, trips, pollution exposure, and policy interventions in the central core, District 12 was also included as a complementary area for spatial sensitivity analysis. The main transport, environmental, health, and financial criteria were defined at the Tehran level, while PM2.5 reduction in District 12 was added to the decision matrix to measure the relative effect of policies in the central core. District 12 results are therefore interpreted as a spatial-sensitivity indicator, not as an independent point forecast for that district. The final criteria were selected to cover three domains: transport effectiveness, pollution and health outcomes, and financial and implementation feasibility. Their selection basis, operational definition, reporting unit, and preferred direction are presented below.

3.2. Source of scenario values, limitations of the upstream model, and conversion to the decision matrix

The values in the decision matrix were extracted from the upstream scenario-modeling layer. This section explains their source, how scenario outputs were converted into comparable criteria, and the limits of inference. Because the present article focuses on the economic and implementation prioritization of alternatives, it does not report the full technical architecture, detailed parameter calibration, or every stage of simulator development. The general mechanism is nevertheless described in sufficient detail to clarify the relationship between the policy scenarios and the decision-matrix values.

The upstream framework is a closed-loop hybrid simulator for analyzing sustainable transport scenarios in Tehran. System dynamics, agent-based modeling, and machine learning interact within an annual cycle and share a common set of variables. The closed-loop structure means that each year's outcomes – including changes in modal shares, congestion, travel costs, fleet status, and fiscal pressure – form part of the initial conditions for the following year. The model therefore produces a continuous trajectory for each alternative over 2024–2030 rather than a set of independent, discrete estimates for different years.

The annual cycle begins by estimating the initial tendency of travel-mode shares. The machine-learning layer estimates this tendency using information from previous years and variables available at the time of prediction. The agent-based layer then adjusts it to reflect the characteristics of each scenario, including access pricing, parking restrictions, fare changes, public transport quality and capacity, the possibility of mode substitution, and the degree of policy compliance. In this framework, agents represent behavioral and implementation responses to policies; they do not simulate every individual traveler or vehicle. The system-dynamics layer subsequently links changes in travel demand and modal shares to outcomes such as vehicle-kilometers traveled, congestion, time loss, energy use, pollutant emissions, health burden, operating costs, subsidy requirements, capital costs, and fiscal pressure on urban management. Each year's results are recorded in the model state and carried into the following year so that gradual effects and policy feedbacks are retained.

Based on this cycle, the decision matrix was produced in four steps. First, the baseline was defined as continuation of the existing trajectory without a new policy intervention. Second, stand-alone policies and combined packages were specified according to the logic and criteria described in Section 3.3. Third, changes relative to the baseline over 2024–2030 were extracted for each alternative and summarized as ten decision criteria. Fourth, C1–C6 were entered as improvements relative to the baseline, whereas C7–C10 were entered as costs, pressures, or undesirable scores. During normalization, the direction of cost criteria was reversed so that a larger normalized value indicated a more desirable condition for every criterion.

The scenario outputs cover such domains as time loss, passenger-car-equivalent vehicle-kilometers traveled, public transport share, PM2.5, the health-cost index, fiscal pressure, capital expenditure, subsidy requirements, and implementation complexity. Rather than being reported merely as simulation results, these outputs were converted into decision-support criteria to enable systematic comparison of the alternatives. The analytical chain therefore begins with the definition of policy levers, proceeds through scenario trajectories and construction of the decision matrix, and after weighting and ranking, concludes with an economic and implementation interpretation of the alternatives.

To assess the baseline pathway, simulated modal shares were compared with historical data for Tehran and District 12. A portion of the final historical-period data was reserved as a holdout test to examine the model's capacity to reconstruct the baseline. The direction and range of changes under each scenario were then checked against the expected mechanism. For example, fleet-emission-reduction policies should have a more direct effect on PM2.5, whereas purely pricing or parking policies, without changes in fleet technology or stronger public transport, do not necessarily produce a large direct effect on pollution. This assessment concerns reconstruction of the baseline at the modal-share level and should not be interpreted as independent validation of all environmental, health, and financial outputs of the simulator.

Unless a terminal-year value is explicitly mentioned, the figures reported in the decision tables are the average effect of each scenario over 2024–2030. Using period averages reduces the dependence of the ranking on a particular year or a short-term effect and provides a more stable representation of policies whose outcomes emerge gradually. At the same time, these values depend on the model structure, behavioral assumptions, input data, intervention intensities, and analytical horizon. They should therefore be regarded as comparative estimates for distinguishing among alternatives rather than as deterministic forecasts of the effects of real-world implementation.

3.3. Policy alternatives and limits of scenario coverage

The alternatives were selected purposively before the weighting and ranking stage. Selection was based on four criteria: first, direct relevance to the problems and policy authority of Tehran's transport management; second, coverage of distinct intervention mechanisms, including demand management, access and parking control, support and improvement of public transport, and changes in fleet emissions and technology; third, the ability to represent each alternative's mechanism in the upstream simulator and extract comparable outputs for 2024–2030; and fourth, avoidance of excessive overlap among alternatives while retaining a decision set of manageable size for interpreting the ranking. These levers also have a place in Tehran's legal and planning documents and in its experience with transport management and clean-air policy (Clean Air Act of Iran, 2017; National Laws and Regulations Portal, 2021; UNESCAP, 2020).

Seven stand-alone scenarios were defined to isolate the effects of the principal policy mechanisms: time-based travel demand management; access pricing; parking management; targeted fare support; improvements in public transport quality, capacity, and reliability; reduction of local emissions from the existing fleet; and transition to a clean taxi and bus fleet. Separating these levers allows for identifying the outcome pattern and the financial and implementation requirements associated with each intervention type independently of the other instruments.

Four combined scenarios were designed to examine instrument complementarity and compare different policy-package architectures, not to cover every mathematically possible combination. Scenario 8 is a light combined package that integrates several low-intensity levers to test whether effectiveness and implementability can be balanced. Scenario 9 represents a push-pull strategy in the central core by combining access and parking restrictions with public transport support and improvement and light fleet clean-up. Scenario 10 focuses on public transport expansion, stronger emission reductions, and fleet transition. Scenario 11 examines an integrated package that simultaneously covers demand management, pricing, parking, service improvement, and fleet technology reform, generally at medium intensities. The four packages thus represent distinct levels and orientations of intervention: a light combined package, a central-core package, a public-transport-oriented clean package, and an integrated package.

The scenario set is not exhaustive of all possible policies; rather, it is a targeted set of representative and comparable options over the study's short- to medium-term horizon. Policies such as extensive transit-oriented development, a comprehensive cycling network, micro-mobility, and artificial intelligence-based interventions were not included because they require a longer horizon, independent data and sub-models, or scenario inputs of comparable quality that were not available. Their exclusion does not imply that they are unimportant; it preserves data consistency and comparability among the selected alternatives. The labels "light," "medium," and "strong" indicate relative intervention levels in the simulator and do not replace the raw outcome and financial values reported in the decision tables. Table 1 defines the components and design logic of the eleven alternatives.

Table 1. Policy alternatives evaluated

Scenario	Policy title	Type	Components and package logic	Design rationale and expected function
Scenario 1	Time-based travel demand management	Stand-alone	Travel-time management, targeted telework, and flexible working hours	Represents temporal demand-management interventions with limited direct capital requirements
Scenario 2	Access pricing for the central area	Stand-alone	Control and pricing of entry to the central core	Represents a pricing instrument for controlling access to the central core
Scenario 3	Parking management in the city center	Stand-alone	Control of curbside parking and stopping in the city center	Represents management of parking spaces and control of car demand in the city center
Scenario 4	Targeted public transport fare support	Stand-alone	Targeted fare subsidies and support for public transport demand	Represents price support for public transport demand
Scenario 5	Public transport service improvement	Stand-alone	Improved quality, reliability, capacity, and accessibility	Represents improvement in public transport supply, quality, and reliability
Scenario 6	Local fleet emissions reduction	Stand-alone	Reduction of local emission intensity from motorcycles, taxis, and buses	Represents reduction of local pollutant-emission intensity in the existing fleet
Scenario 7	Transition to a clean fleet	Stand-alone	Renewal and electrification of taxis and buses	Represents fleet renewal and technological transition
Scenario 8	Light package	Combined	Scenario 1 + Scenario 3 (light) + Scenario 4 + Scenario 6 (medium)	Tests the complementarity of several low-intensity levers
Scenario 9	Central-core management package with a push-pull approach	Combined	Scenario 2 + Scenario 3 (light) + Scenario 4 (medium) + Scenario 5 (medium) + Scenario 6 (light)	Tests a push-pull package focused on the central core
Scenario 10	Public-transport-oriented clean package	Combined	Scenario 4 + Scenario 5 + Scenario 6 (strong) + Scenario 7 (medium) + Scenario 3 (light)	Tests a package of public transport expansion, fleet clean-up, and fleet transition
Scenario 11	Balanced integrated package	Combined	Scenario 1 (medium) + Scenario 2 (medium) + Scenario 3 (medium) + Scenario 5 + Scenario 6 (medium) + Scenario 7 (medium)	Tests an integrated package covering demand, access, service, and technology

Table 2. Quality control of scenario values at the modal-share level

Domain	Control period	R^2	MAE (percentage points)	RMSE (percentage points)
Tehran	Historical reconstruction, 2012–2023	0.994	0.644	1.226
District 12	Historical reconstruction, 2012–2023	0.947	1.148	1.614
Tehran	Holdout test, 2022–2023	0.984	1.570	2.318
District 12	Holdout test, 2022–2023	0.694	2.757	3.929

To supplement the numerical checks in Table 2, Figure 1 presents the historical reconstruction of modal shares and the projected scenario trajectories for Tehran and District 12. The figure is not intended to report the complete architecture of the upstream model; rather, it clarifies the origin of the baseline pathway and the limits within which the scenario results should be interpreted. Tehran is the primary decision-making and ranking domain, while District 12 is used as a sensitivity indicator for the central core. District 12 results should therefore be interpreted mainly in terms of direction, relative magnitude, and consistency with the policy mechanism, rather than as independent point forecasts.

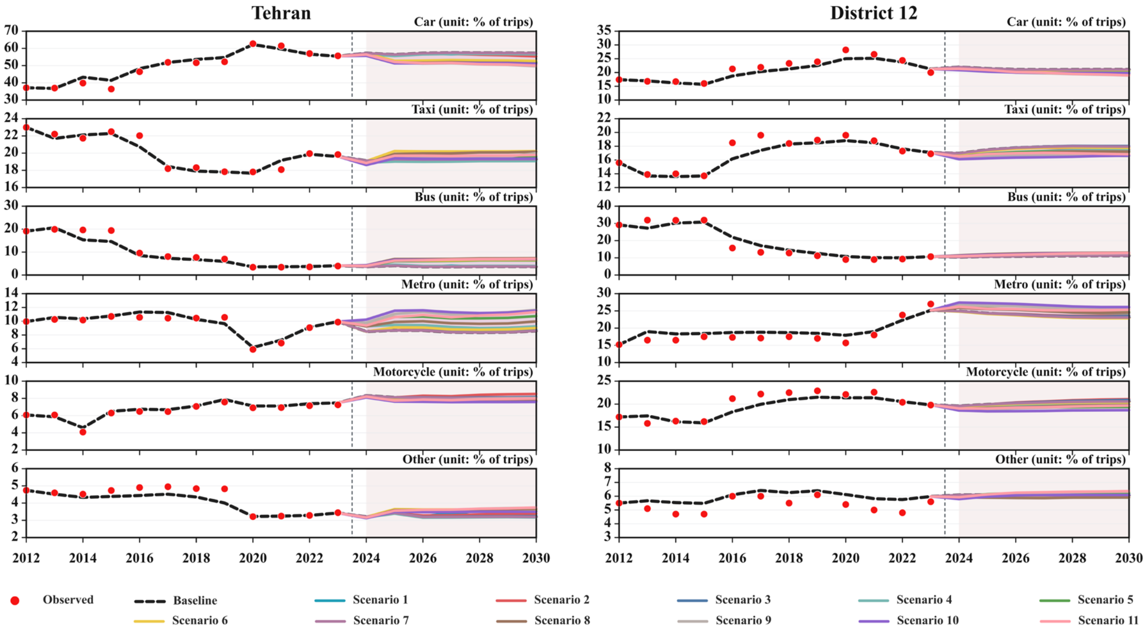

Figure 1. Historical reconstruction and projected modal-share trajectories in Tehran and District 12

*Red points show historical observations; the black dashed line represents the baseline pathway; and the colored lines show the policy-scenario trajectories. The historical period is used to assess baseline reconstruction, and 2024–2030 is used to display the range of scenario trajectories. Values are reported as percentages of trips.

3.4. Decision criteria and the basis for their selection

The decision criteria were selected to cover three domains simultaneously: transport effectiveness, environmental and health outcomes, and financial and implementation feasibility. Because of limitations in household microdata and detailed distributional information, accessibility equity, social-distributional effects, and spatial justice were not entered independently into the decision matrix and are considered only interpretively in the policy discussion. Table 3 presents each criterion's type, reporting unit, preferred direction, and interpretive role. C1–C6 are benefit criteria for which larger values are preferable, whereas C7–C10 are cost criteria for which smaller values are preferable. Some criteria, particularly C6, C7, and C10, are index-based and are used for relative scenario comparison rather than as independent monetary or institutional estimates.

Table 3. Decision criteria

Code	Criterion title	Type	Reporting unit	Preferred direction	Interpretive role / operational definition
C1	Reduction in car time loss in Tehran	Benefit	Percentage change relative to baseline	Higher is better	Reduction in congestion and time lost
C2	Reduction in passenger-car-equivalent vehicle-kilometers traveled in Tehran	Benefit	Percentage change relative to baseline	Higher is better	Reduction in the load on the car-oriented network
C3	Increase in public transport share	Benefit	Relative percentage change from baseline	Higher is better	Shift in the travel pattern toward collective transport
C4	Reduction in PM2.5 in Tehran	Benefit	Percentage change relative to baseline	Higher is better	Improvement in metropolitan air quality
C5	Reduction in PM2.5 in District 12	Benefit	Percentage change relative to baseline	Higher is better	Central-core sensitivity indicator, not an independent point forecast
C6	Index of reduction in PM2.5-related health costs in Tehran	Benefit	Percentage change relative to baseline	Higher is better	Relative index linking PM2.5 reduction to lower health burden and social costs
C7	Net fiscal pressure index	Cost	Relative dimensionless index	Lower is better	Relative pressure of the policy on urban-management resources
C8	Implementation capital expenditure	Cost	Billion rials/year, horizon average	Lower is better	Investment and infrastructure requirements
C9	Increase in public transport subsidy requirements	Cost	Percentage change relative to baseline	Lower is better	Recurrent commitment and operating pressure
C10	Implementation complexity	Cost	Score from 1 to 5	Lower is better	Screening of the institutional, technical, and social capacity required for implementation

In Table 3, C1–C6 are reported as improvements relative to the baseline, and larger values are preferable. C3 represents the relative increase in the share of public transport compared with the baseline and should not be interpreted as an increase in percentage points. C7 is a dimensionless relative index of net fiscal pressure. C8 reports average annual implementation capital expenditure over the analytical horizon in billion rials per year. C9 is the percentage change in public transport subsidy requirements relative to the baseline. C10 is an implementation complexity score that ranges from 1 to 5, with a lower value being preferable. C6 is a relative index of the reduction in health burden or health costs associated with PM2.5 and should not be interpreted as an independent monetary estimate of all health outcomes.

The ten criteria were selected for their direct relevance to the implementation priorities of Tehran's urban management. The upstream simulation layer produces other important indicators, but not all possible outputs were entered as independent criteria to avoid overlap and preserve transparency in the ranking. In particular, C10 (implementation complexity) is designed as an overall screening score and is not a substitute for a detailed institutional assessment.

3.5. Raw decision matrix and interpretive notes

The raw decision matrix consists of eleven policy alternatives and ten criteria. The reported values are the average changes under each scenario relative to the baseline over 2024–2030. Because the criteria differ in units and scales, values across different criteria cannot be compared directly before normalization; performance can nevertheless be compared among alternatives within each criterion. For readability, the matrix is presented in two parts: Table 4 reports the transport, environmental, and health criteria, and Table 5 reports the financial and implementation criteria.

In Table 4, C1–C6 are benefit criteria, and larger values indicate greater improvement relative to the baseline. For C1, C2, C4, C5, and C6, a positive value denotes a reduction in an undesirable indicator, whereas for C3 it denotes a relative increase in the public transport share. C3 should not be interpreted as an increase in percentage points. Small negative values for C4 and C5 in some scenarios indicate a limited increase in PM2.5 relative to the baseline; the policy interpretation of this pattern is presented in the Discussion section.

Table 4. Raw decision matrix: transport, environmental, and health criteria, percentage change relative to the baseline, averaged over 2024–2030

Scenario	C1: Reduction in car time loss in Tehran	C2: Reduction in PCE-VKT in Tehran	C3: Relative increase in public transport share in Tehran	C4: Reduction in PM2.5 in Tehran	C5: Reduction in PM2.5 in District 12	C6: Reduction in health-cost index in Tehran
Scenario 1	5.44	2.28	1.87	2.19	0.14	1.17
Scenario 2	1.69	0.51	2.92	-0.05	-0.46	0.27
Scenario 3	0.33	0.09	0.49	0.00	-0.24	0.05
Scenario 4	2.38	1.03	8.70	0.47	1.56	0.40
Scenario 5	11.67	4.44	33.30	2.93	2.40	2.24
Scenario 6	9.22	3.19	22.52	9.98	20.98	3.24
Scenario 7	-0.01	0.00	0.00	0.75	1.26	0.60
Scenario 8	16.36	6.52	34.79	9.86	15.03	4.29
Scenario 9	14.56	5.59	42.01	5.44	8.51	3.20
Scenario 10	14.42	5.73	44.53	9.51	19.58	4.06
Scenario 11	16.20	6.44	39.33	9.05	14.65	4.31

Table 4 reports the average percentage change over 2024–2030 relative to the baseline. For C1, C2, C4, C5, and C6, a positive value indicates a reduction in an undesirable indicator; for C3, a positive value indicates a relative increase in the share of public transport. Figure 2 presents the annual trajectories of C1–C6 for the baseline and the policy alternatives, allowing comparison between the average period effect and its development over time.

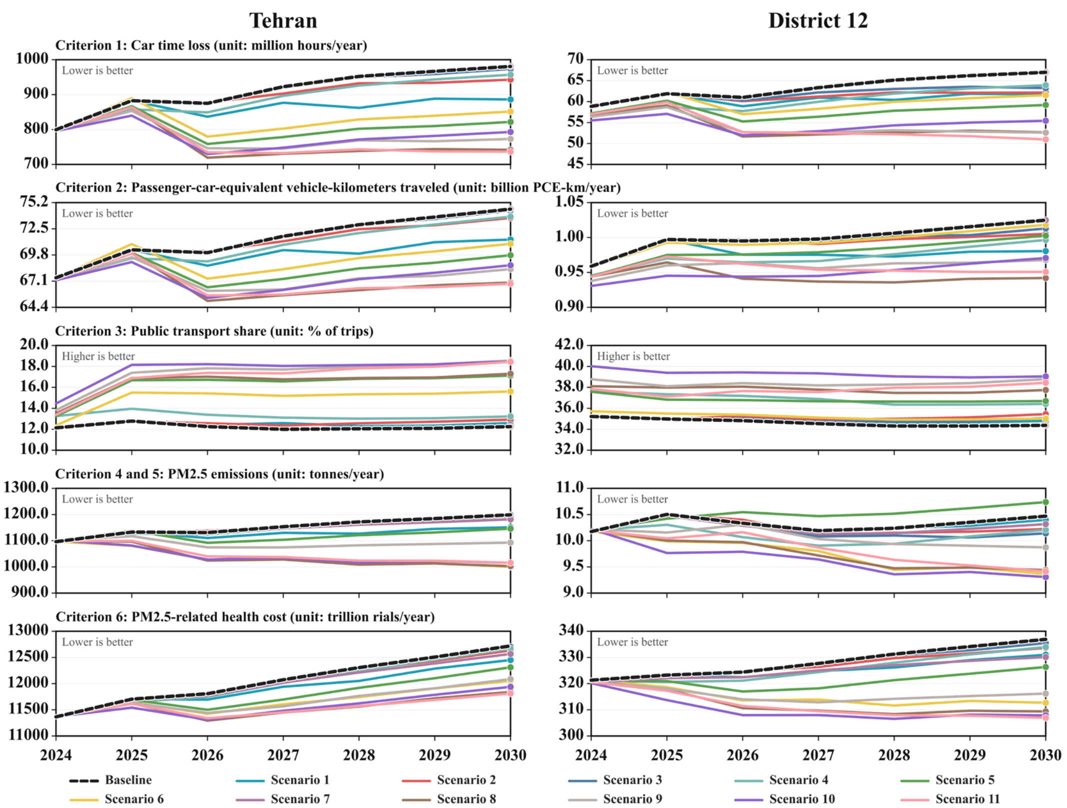

Figure 2. Annual trajectories of selected decision indicators over 2024–2030

*The figure shows the baseline and policy-scenario trajectories for the principal criteria reported in Table 4.

In Table 5, C7–C10 are cost criteria, and lower values are preferable. C7 is the dimensionless relative index of net fiscal pressure; C8 is average annual capital expenditure; C9 is the percentage change in public transport subsidy requirements relative to the baseline; and C10 is the implementation complexity score on a scale of 1 to 5. A zero value for C8 in some scenarios does not imply the absence of all administrative and implementation costs; it indicates that no substantial direct infrastructure capital expenditure was assigned to that alternative in the matrix definition. A negative C9 value indicates a small reduction in subsidy requirements relative to the baseline.

Table 5. Raw decision matrix: financial and implementation criteria over 2024–2030, reported in the criterion-specific units

Scenario	C7: Net fiscal pressure (dimensionless index)	C8: Capital expenditure (billion rials/year)	C9: Public transport subsidy requirement (% relative to baseline)	C10: Implementation complexity (score 1–5)
Scenario 1	0.0007	0.00	-0.06	1.00
Scenario 2	0.0083	236.73	4.19	1.50
Scenario 3	0.0015	43.49	0.73	1.50
Scenario 4	0.0318	0.00	12.50	1.20
Scenario 5	0.1369	21235.44	51.60	3.00
Scenario 6	0.1174	1026.88	48.55	2.00
Scenario 7	0.0296	4441.75	12.15	3.20
Scenario 8	0.1588	684.86	65.01	2.50
Scenario 9	0.1684	17456.17	66.30	3.50
Scenario 10	0.2053	25582.15	79.03	4.50
Scenario 11	0.1815	25545.88	70.52	4.20

The values in Table 5 have different units and should not all be read as percentage changes. Their normalization and orientation before weighting and ranking are explained in Section 3.6. To provide a comparative overview of the alternatives' performance patterns, Figure 3 shows the relative position of the eleven scenarios in the domains of transport, air and health, financial feasibility, and ease of implementation. This is not the final ranking; it is presented only to illustrate differences in scenario profiles before TOPSIS is applied.

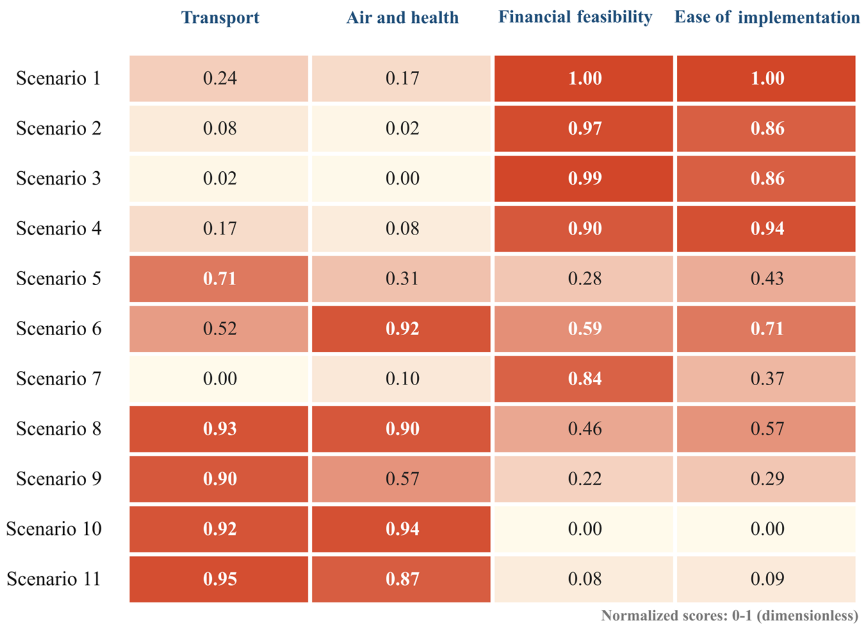

Figure 3. Comparative performance profiles of the eleven policy alternatives

3.6. Normalization and weighting

Because the decision criteria differ in units, scales, and preferred directions, all criteria were normalized and oriented consistently before weighting and ranking. For benefit criteria, the normalized value was obtained from the following equation:

$$r_{ij} = \frac{x_{ij} - \min(x_j)}{\max(x_j) - \min(x_j)} \qquad (1)$$

For cost criteria, the criterion direction was reversed so that a larger value represented a more desirable condition for every criterion:

$$r_{ij} = \frac{\max(x_j) - x_{ij}}{\max(x_j) - \min(x_j)} \qquad (2)$$

In these equations, x_ij is the raw value of alternative under criterion , and is its normalized, consistently oriented value. After this step, all criteria ranged from zero to one and could be entered into the weighting and ranking procedures.

Objective criterion weights were calculated using the CRITIC method. This method determines the importance of each criterion based on two properties: its dispersion among the alternatives and the amount of non-redundant information it contains relative to the other criteria. A criterion that creates greater differentiation among alternatives and has less overlap with other criteria therefore receives a higher weight. The information content of criterion j (C_j) was calculated as follows:

$$C_j = s_j \times \sum_{k=1}^{m} (1 - \rho_{jk}) \qquad (3)$$

where is the standard deviation of criterion j and ρ_{jk} is the correlation coefficient between criteria j and k. The weight of criterion j was then obtained from the following equation:

$$w_j = \frac{C_j}{\sum_{j=1}^{m} C_j} \qquad (4)$$

In addition to the CRITIC weights, four policy-oriented weighting structures were defined for sensitivity analysis: balanced weighting, clean-air priority, transport priority, and financial-implementation priority. These weights do not represent definitive preferences of decision-makers; they are analytical structures used to test the robustness of the results. Each weighting structure represents a hypothetical decision environment in which the policymaker places greater weight on one dimension of the problem. Consequently, stability across several weighting structures is more important for interpretation than the rank of an option in a single column. Table 6 presents the weights used in the analysis.

Table 6. Criterion weights under alternative weighting structures

Criterion	CRITIC	Balanced	Clean air	Transport	Financial/implementation
C1	0.086	0.130	0.080	0.230	0.080
C2	0.085	0.080	0.040	0.150	0.040
C3	0.093	0.120	0.070	0.220	0.060
C4	0.087	0.130	0.220	0.070	0.070
C5	0.082	0.130	0.240	0.060	0.060
C6	0.084	0.100	0.140	0.060	0.070
C7	0.129	0.100	0.070	0.070	0.220
C8	0.123	0.080	0.050	0.050	0.170
C9	0.131	0.060	0.040	0.040	0.120
C10	0.100	0.070	0.050	0.050	0.110

Weights are dimensionless and sum to 1 under each weighting structure.

3.7. Ranking with TOPSIS

After normalization, consistent orientation, and weighting, the alternatives were ranked using TOPSIS. The method assumes that a desirable alternative should simultaneously be as close as possible to the positive ideal solution and as far as possible from the negative ideal solution. The weighted normalized matrix was first calculated as follows:

$$v_{ij} = w_j \times r_{ij} \qquad (5)$$

In this equation, w_j is the weight of criterion j, r_{ij} is the normalized and consistently oriented value of alternative i under criterion j, and v_{ij} is its weighted value. Because all criteria were oriented consistently in the previous step, the positive and negative ideal solutions for each criterion are defined respectively as the maximum and minimum weighted values:

$$A^{+} = \{\max(v_{ij})\}, \quad A^{-} = \{\min(v_{ij})\} \qquad (6)$$

The distance of each alternative from the positive and negative ideal solutions was then calculated using the following equations:

$$D_i^{+} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - A_j^{+}\right)^2} \qquad D_i^{-} = \sqrt{\sum_{j=1}^{m} \left(v_{ij} - A_j^{-}\right)^2} \qquad (7)$$

Finally, the relative closeness score of each alternative was obtained from the following equation:

$$CC_i = \frac{D_i^{-}}{D_i^{+} + D_i^{-}} \qquad (8)$$

The value of CC_i lies between zero and one; a larger value indicates greater proximity to the ideal solution and a better rank. The final alternatives were ranked in descending order of CC_i.

4. Findings

The CRITIC weighting results show that financial and implementation criteria – particularly public transport subsidy requirements, net fiscal pressure, and capital expenditure – account for a substantial share of the criterion weights. The combined weight of C7–C10 is 0.483 (Table 6); that is, almost half of the objective weight in the decision problem is associated with financial and implementation feasibility. This result indicates that, in evaluating Tehran's transport policies, financial and implementation criteria play a decisive role alongside transport, environmental, and health outcomes. The rankings are based on average scenario outcomes over 2024–2030 and, given the model and data limitations, are interpreted together with sensitivity tests. Table 7 reports the TOPSIS scores and ranks under five weighting structures.

Table 7. Ranking results of the alternatives using TOPSIS

Scenario	Balanced score	Balanced rank	CRITIC rank	Clean-air rank	Transport rank	Financial / implementation rank
Scenario 8	0.721	1	2	2	1	7
Scenario 6	0.675	2	1	1	6	5
Scenario 11	0.630	3	8	4	2	10
Scenario 10	0.627	4	10	3	4	11
Scenario 9	0.576	5	9	5	3	8
Scenario 5	0.455	6	11	6	5	9
Scenario 1	0.421	7	3	7	7	1
Scenario 4	0.369	8	4	8	8	4
Scenario 2	0.356	9	5	10	9	2
Scenario 3	0.351	10	6	9	10	3
Scenario 7	0.310	11	7	11	11	6

The TOPSIS score is dimensionless and ranges from zero to one; a larger value indicates that an alternative is closer to the ideal solution. Under balanced weighting, Scenario 8 ranked first with a score of 0.721, followed by Scenarios 6 and 11 in second and third place. Scenarios 10, 9, and 5 ranked fourth through sixth. Scenarios 1, 4, 2, 3, and 7 occupied ranks seven through eleven.

Changing the weighting structure shifted the positions of several alternatives. Under CRITIC weighting, Scenario 6 ranked first, Scenario 8 second, and Scenario 1 third. In the clean-air-priority structure, Scenarios 6, 8, and 10 ranked as the top three options. Under transport priority, Scenario 8 ranked first, followed by Scenarios 11 and 9. Under financial and implementation priority, Scenarios 1, 2, and 3 occupied the top three positions, while Scenarios 10 and 11 fell to eleventh and tenth. These shifts show that alternative rankings depend on the relative emphasis placed on effectiveness or feasibility. Figure 4 presents the relative positions of the alternatives in terms of effectiveness and implementation feasibility.

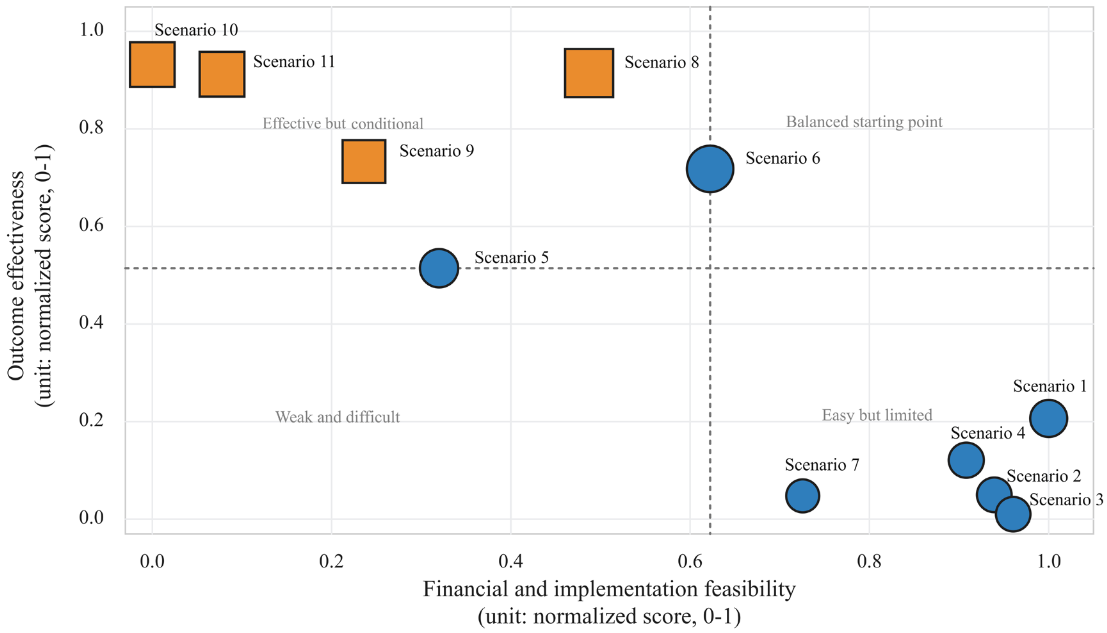

Figure 4. Policy-position map based on effectiveness and implementation feasibility

As Figure 4 shows, some alternatives produce larger transport and environmental outcomes but face greater constraints in cost, subsidy requirements, or implementation complexity. Others are simpler and less costly to implement but address a narrower range of effects. Under balanced weighting, Scenario 8 occupies a position in which relatively high effectiveness is combined with lower capital expenditure and complexity than the heavier packages. Scenario 6 also performs strongly on pollution and health, whereas Scenario 1 is more favorable on financial and implementation criteria.

To assess rank stability, the alternatives were compared across the five weighting structures. Table 8 summarizes rank changes for selected alternatives. Scenario 8 appeared among the top three under four of the five structures and had a mean rank of 2.6. Scenario 6 was among the top three under three structures and recorded a mean rank of 3. Scenarios 1 and 11 each appeared in the top three under two structures, whereas Scenarios 9 and 10 did so under one structure each.

Table 8. Summary of rank sensitivity

Scenario	Best rank	Worst rank	Mean rank	Top-three appearances	Interpretation
Scenario 8	1	7	2.6	4	Balanced option and the most stable initial package
Scenario 6	1	6	3.0	3	Clean-air pillar and particulate-matter reduction
Scenario 1	1	7	5.0	2	Immediate action under fiscal constraints
Scenario 11	2	10	5.4	2	Effective but conditional package
Scenario 9	3	9	6.0	1	Central-core package requiring implementa-tion capacity
Scenario 10	3	11	6.4	1	Strong clean package, but financially and operationally demanding

The rank range across the five weighting structures indicates the stability of each alternative.

In Table 8, Scenario 8 has a best rank of 1 and a worst rank of 7. Scenario 6 ranges from rank 1 to 6, and Scenario 1 from rank 1 to 7. The broader packages, especially Scenarios 10 and 11, rank higher under effectiveness-oriented structures but experience larger declines under financial and implementation weighting. Figure 5 displays the range of rank changes across the five weighting structures.

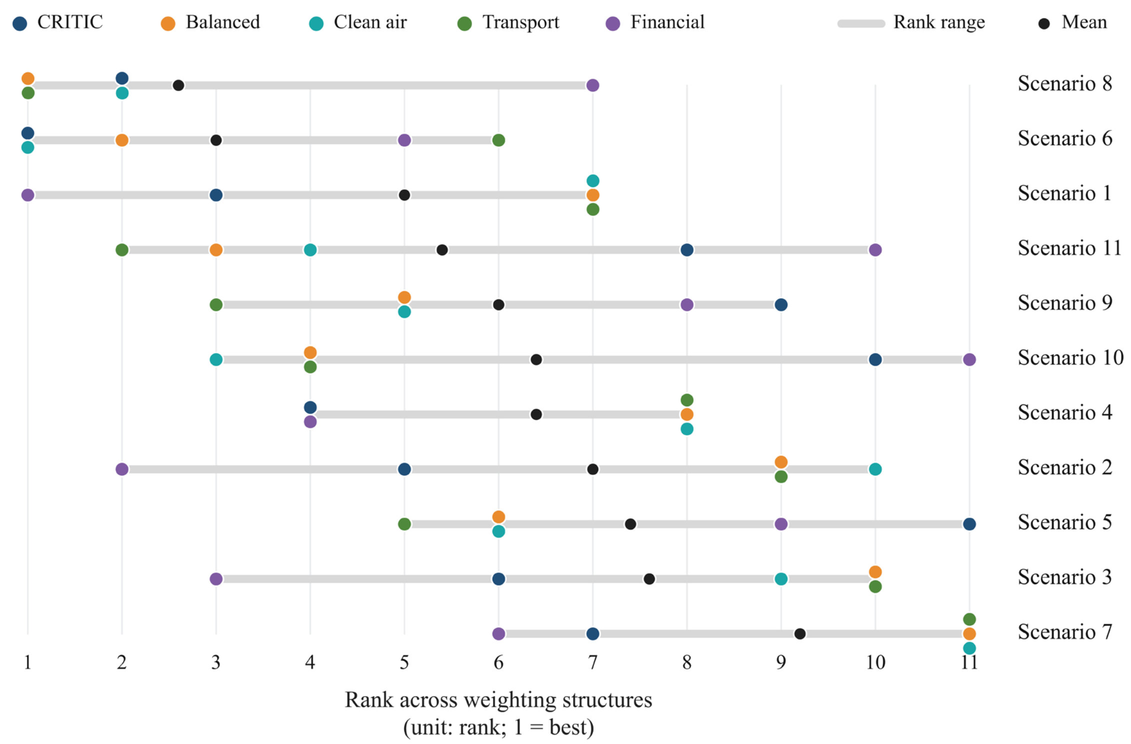

Figure 5. Rank stability of the alternatives across five weighting structures

Figure 5 shows that the positions of the principal alternatives respond differently to changes in criterion weights. Scenarios 8 and 6 retain high ranks under several weighting structures, while Scenario 1 improves as greater weight is assigned to financial and implementation criteria. Conversely, Scenarios 10 and 11 move to lower ranks as financial and implementation feasibility receives greater weight. The sensitivity analysis therefore avoids reliance on a single weighting structure and reveals how alternatives perform under different decision conditions.

To examine whether the results depend on the ranking method, a complementary test was conducted using the simple additive weighting method (SAW). Figure 6 shows the relationship between balanced TOPSIS and SAW scores. The broad alignment of the two sets of scores and the location of higher-scoring alternatives in a similar region of the plot indicate that the relative position of the main alternatives does not depend solely on a single aggregation method. Under SAW, Scenarios 8 and 6 also remained among the leading alternatives under balanced weighting, and Scenario 1 retained first place under the financial and implementation structure. This does not imply that the two methods produce identical rankings; rather, it shows that the overall ranking message is not fundamentally altered by changing the aggregation rule.

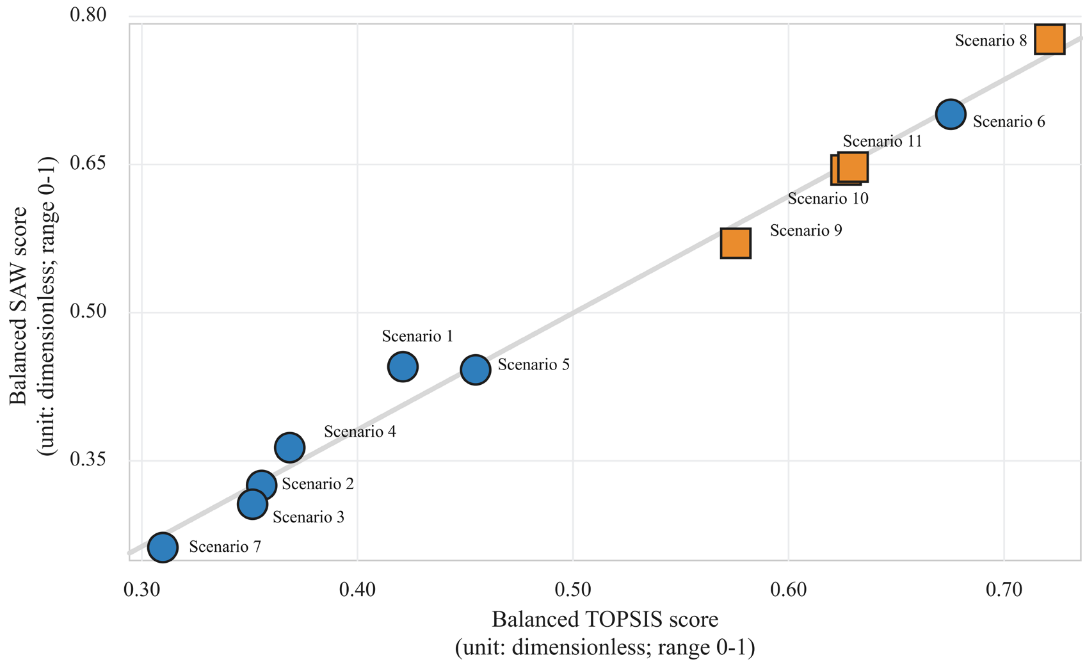

Figure 6. Comparison of balanced TOPSIS and SAW scores as a robustness check on the ranking method

In addition to the TOPSIS-SAW comparison, several supplementary tests examined sensitivity to criteria and weights. Under equal weighting, after removing C10, halving the weight of C10, and removing C5, Scenarios 8 and 6 remained in the top two positions under the balanced structure. Removing C5 showed that their positions were not driven solely by the District 12 PM2.5 criterion. When only the effectiveness criteria C1–C6 were retained, Scenarios 10 and 11 moved to higher positions. By contrast, when the analysis was based only on the feasibility criteria C7–C10, Scenario 1 ranked first. These results reveal the distinction between effectiveness-based and feasibility-based ranking.

To make the implementation-complexity criterion more transparent, Table 9 reports the scores for the five components of C10: physical investment, number of institutions involved, social sensitivity, technological or fleet dependence, and monitoring and enforcement difficulty. The components were assigned equal weights, and C10 was calculated as their mean. Table 9 shows that Scenario 1, with a score of 1, has the lowest implementation complexity. Scenarios 2 and 3, with scores of 1.5, are also in the low-complexity range. Scenario 8, with a score of 2.5, is at an intermediate level, whereas Scenarios 10 and 11, with scores of 4.5 and 4.2, have the highest implementation complexity. These differences are consistent with the rank changes under the financial and implementation structure. C10 is designed for relative comparison of implementation requirements and is not a substitute for a detailed institutional assessment.

Overall, the ranking and sensitivity results reveal three principal patterns. First, some alternatives maintain relatively stable positions across several weighting structures. Second, broader packages perform better on effectiveness criteria but lose rank on financial and implementation criteria. Third, simpler alternatives with lower capital requirements perform better under financial and implementation weighting but occupy lower positions in terms of scope of effect. The policy interpretation of these patterns and the role of each alternative in the implementation sequence are discussed in the following section.

Table 9. Components of the implementation-complexity criterion

Scenario	Physical investment	Number of institutions	Social sensitivity	Technology/fleet dependence	Monitoring/enforce-ment difficulty	C10
Scenario 1	1.0	1.0	1.0	1.0	1.0	1.0
Scenario 2	1.0	2.0	2.5	1.0	1.0	1.5
Scenario 3	1.5	1.5	1.5	1.0	2.0	1.5
Scenario 4	1.0	1.5	1.5	1.0	1.0	1.2
Scenario 5	3.5	3.0	2.5	2.5	3.5	3.0
Scenario 6	2.0	2.0	1.5	2.5	2.0	2.0
Scenario 7	4.0	3.0	1.5	4.5	3.0	3.2
Scenario 8	2.0	2.5	2.0	3.0	3.0	2.5
Scenario 9	3.0	4.0	4.0	2.5	4.0	3.5
Scenario 10	5.0	4.5	3.5	5.0	4.5	4.5
Scenario 11	5.0	4.5	4.0	4.0	3.5	4.2

Component scores range from 1 to 5; lower values are preferable; and C10 is the mean of the five components.

5. Discussion and interpretation of findings

The findings indicate that prioritizing sustainable transport policies in Tehran requires balancing two sets of considerations: the degree of improvement in transport, environmental, and health outcomes, on the one hand, and the financial, institutional, and implementation capacity required to achieve those outcomes, on the other. The policy-position map in Figure 4 illustrates this tension. Some alternatives are more effective but less implementable, while others are easier to implement but address only a limited part of the problem. First place should therefore not be interpreted as absolute superiority of one policy under all conditions; each alternative should be understood in light of its appropriate role in the implementation process.

Within this framework, Scenario 8 (the light combined package) ranked first under balanced weighting with a TOPSIS score of 0.721 and remained among the top three alternatives under four of the five weighting structures (Tables 7 and 8, and Figure 5). The importance of this result is that the position of Scenario 8 does not depend solely on one policy priority or a particular set of weights. The package combines, at controlled intensities, several complementary instruments: time-based travel demand management, light parking management, targeted public transport fare support, and medium-intensity reduction of local fleet emissions. Its advantage therefore arises less from maximizing a single outcome than from avoiding pronounced drawbacks across the different dimensions of the decision problem, as shown in the strategic performance profiles in Figure 7.

This finding is consistent with the system-modeling literature on transport, which emphasizes the interrelationships among travel demand, network capacity, service quality, cost, and environmental outcomes. Under this perspective, an intervention in one part of the system may fail to produce its full expected effect because of behavioral feedbacks or constraints elsewhere. Studies of integrated urban policies likewise emphasize that a coordinated combination of demand-management instruments, strengthened alternative travel options, and technological reform can address a broader range of sustainability objectives than stand-alone interventions (Haghshenas et al., 2015; Melkonyan et al., 2020; Rassafi et al., 2014). The present study differs from much of this literature because scenario effects are not used as the sole basis for the decision; capital expenditure, fiscal pressure, subsidy requirements, and implementation complexity are also entered directly into the prioritization. A package with greater technical effects is therefore not necessarily the most suitable option for immediate initiation.

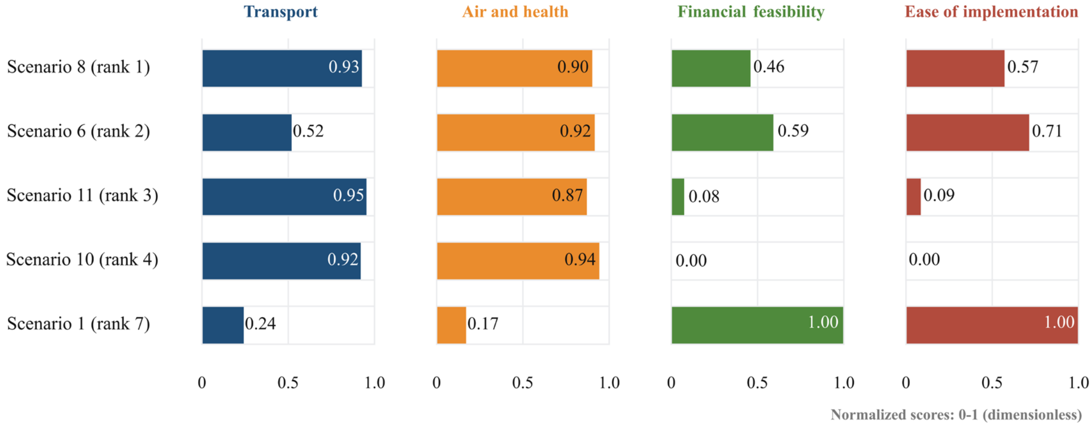

Figure 7. Strategic performance profiles of selected alternatives

The description of Scenario 8 as "low risk" must nevertheless be interpreted relatively. Its 65.01% increase in public transport subsidy requirements and seventh-place rank under financial and implementation priority indicate that it, too, cannot be implemented without a sustainable funding source (Tables 5 and 7). The package is lower-risk primarily because its capital expenditure and complexity are lower than those of the heavy development packages, not because it creates no fiscal pressure. A more precise description is therefore a "balanced initial package with more manageable implementation risk than the development packages." Its implementation should include a clearly defined source of subsidy funding, a limit on ongoing commitments, and a phased monitoring mechanism.

Scenario 6 (reduction of local fleet emissions) ranked first under both CRITIC weighting and the clean-air-priority structure. Its PM2.5 reductions relative to the baseline in Tehran and District 12 (9.98% and 20.98%, respectively) provide empirical support for its position in clean-air policy (Table 4). The larger effect in District 12 is consistent with the concentration of activities, traffic density, and greater exposure in the central core. Because validation is less accurate at the District 12 scale, however, this value should be interpreted chiefly in terms of direction and relative magnitude rather than as a deterministic forecast. The importance of Scenario 6 is consistent with emission studies for Tehran, which emphasize the role of mobile sources, motorcycles, and medium/heavy/diesel-powered vehicles in local pollutant emissions and identify renewal or lower emission intensity in the public fleet as important components of particulate-matter control (Shahbazi et al., 2016, 2019; Tahsiri & Arab, 2023; Vafa-Arani et al., 2014). Positioning fleet-emission reduction as a central short-term clean-air policy is therefore consistent with previous evidence. At the same time, this policy does not directly alter travel demand or network pressure and cannot, by itself, replace demand management and public transport development.

The comparison between Scenarios 6 and 7 clarifies this difference in mechanism. Scenario 7 (transition to a clean taxi and bus fleet) is important as a technology-based emissions-reduction measure. But its effect on time loss is approximately zero, and it also ranks low under effectiveness-oriented structures (Tables 4 and 7, and Figure 3). This does not mean that electrification is unimportant. Rather, it shows that changing propulsion technology, without changing travel demand, the price of car use, parking management, or the quality of public transport service, is not an independent congestion-reduction policy. A full assessment of the environmental benefits of electrification also depends on the electricity-generation mix, charging infrastructure, battery life, and life-cycle impacts. Clean fleet technology should therefore be embedded in a broader package of technology, service, and demand management.

Scenario 1 (time-based travel demand management) ranked first under the financial and implementation priority structure. Its complexity score of 1 out of 5 and the absence of substantial direct and infrastructure investment in the decision-matrix definition explain why it can be initiated more rapidly (Tables 5, 7, and 9). Its lower position under balanced weighting, however, indicates that although the policy can reduce peak-period pressure and provide an appropriate opportunity for implementation, it does not address every dimension of Tehran's transport and air-pollution problems. Scenario 1 should therefore be interpreted as an immediate and enabling action, not as the final solution.

The findings for access pricing and parking management likewise show that restricting car use, without strengthening alternative travel options and reducing fleet-emission intensity, does not necessarily produce simultaneous improvements in congestion and pollution. The profiles of these alternatives in Table 4 and Figure 3 show that their effects are uneven across domains. This is consistent with Tehran studies indicating that pricing design can affect mode choice, while the final consequences of access restrictions depend on public transport quality, urban spatial structure, and the possibility of substituting trips or modes (Mamdoohi & Hamrang Ghoortlar, 2021; Salarvandian et al., 2017). Access pricing and parking management in Tehran should therefore be used primarily as components of a push-pull package rather than as stand-alone policies for solving congestion and pollution simultaneously. Scenario 5 (public transport service improvement), by contrast, shows that better quality, capacity, accessibility, and reliability can produce substantial transport outcomes; however, its capital and subsidy requirements reduce its position under financial and implementation weighting (Tables 4, 5, and 7). This reflects a basic tension in Tehran policy: public transport is essential to the success of instruments that restrict car use, but its development and maintenance require stable resources and operating capacity. The intensity and timing of service expansion programs must therefore be aligned with the capacity to finance both capital and recurrent expenditure.

This tension is even more evident in Scenario 10 (the public-transport-oriented clean package) and Scenario 11 (the balanced integrated package). Both are among the stronger alternatives in terms of transport and environmental outcomes, but under financial and implementation priority they rank eleventh and tenth, respectively. Their average annual capital expenditure is approximately 25.6 trillion rials each, and their implementation complexity is at the upper end of the scale (Tables 5, 7, and 9). Their decline in rank therefore does not reflect weak effectiveness; it reflects constraints on initiating and sustaining implementation. These packages should be treated as development options whose execution depends on sustainable financing, a clear subsidy program, multi-institutional coordination, and long-term maintenance and operating capacity.

Tehran's characteristics play a decisive role in producing this ranking pattern. The concentration of a substantial share of administrative, commercial, and service activities in the central core means that access policies and fleet-emission reductions can have different effects in District 12 than across the city as a whole. Fleet heterogeneity and aging, together with the widespread presence of motorcycles, taxis, and diesel vehicles, further increase the importance of controlling emission intensity. At the same time, differences in public transport quality and accessibility across the city mean that car restrictions without a reliable alternative may reduce acceptance or shift demand toward undesirable modes.

Limited municipal financial resources and ongoing subsidy commitments also make it difficult to implement several capital-intensive packages simultaneously. This interpretation is consistent with research on Tehran Municipality's fiscal sustainability and municipal budget deficits, which emphasizes unstable revenue sources and the pressure of financial commitments (Ahmadi et al., 2022; Jafari Shahrestani et al., 2022). In addition, the number of institutions responsible for pricing, traffic management, public transport development, technical inspection, fleet renewal, and working-hour regulation increases coordination costs and the likelihood of incomplete implementation. A policy that could be implemented simultaneously in a city with greater resources and institutional capacity may therefore require phasing and additional prerequisites in Tehran.

The differences between the present results and those of some effectiveness-oriented studies should not be interpreted as scientific inconsistency. When evaluation focuses solely on transport and environmental effects, broader packages such as Scenarios 10 and 11 move to higher positions, as shown by the test restricted to effectiveness criteria. When the focus shifts to feasibility criteria, low-capital and simpler alternatives such as Scenario 1 rise to the top. The final result therefore depends not only on the policy mechanism but also on the scope of the decision criteria and the city's institutional and fiscal conditions. In Tehran, implementation constraints are part of the policy problem itself and cannot be set aside after an alternative has been selected.

The study's contribution lies less in applying a particular ranking method than in the interpretation derived from the results. "Greater effectiveness" and "higher priority for initial implementation" are not necessarily the same. Some packages have stronger transport and environmental effects, but their capital, subsidy, and institutional constraints reduce the feasibility of immediate implementation. Simpler alternatives, despite a narrower effect, may be more suitable starting points. This distinction transforms ranking from selecting a single superior alternative into a tool for identifying the role, timing, and implementation conditions of policies, thereby strengthening the link between policy-outcome evaluation and implementation decisions.

The principal implication is therefore the need for a phased and revisable implementation pathway. Time-based travel demand management can serve as an immediate action; reduction of local fleet emissions can simultaneously form the short-term pillar of clean-air policy; and Scenario 8 can be implemented as a balanced initial package. Progress toward more capital-intensive and integrated packages, especially Scenarios 10 and 11, should be conditional on sustainable financing, operating capacity, and interinstitutional coordination. The different roles of these alternatives are illustrated in Figure 7. Access pricing and parking management should be complemented by enhanced alternative travel options and a transparent allocation of revenues towards public transport, fleet emission reduction, and support for vulnerable groups. The sensitivity analysis indicates that the main message is not restricted to a single weighting structure or aggregation method. However, priorities may vary based on the set of alternatives, criteria, scenario intensities, and analytical horizons. Therefore, the implementation of policies should include periodic monitoring and review.

6. Conclusion

This study evaluated eleven alternatives, including seven stand-alone policies and four combined packages, over 2024–2030 to establish an economic and implementation prioritization of sustainable transport policies in Tehran. The decision-matrix data were extracted from an upstream hybrid simulator based on system dynamics, agent-based modeling, and machine learning. Ten decision criteria covered transport outcomes, pollution and health cost reductions, and financial and implementation feasibility. Criterion weights were determined using CRITIC and alternatives were ranked using TOPSIS; robustness was examined across five weighting structures and a set of sensitivity tests.

The results identify Scenario 8 (the light combined package) as the most suitable option for a balanced start. However, its increased public transport subsidy requirement shows that its superiority does not mean that it is absolutely low-cost, and a specified funding source and controls on recurrent commitments must support its implementation.

Among the stand-alone policies, Scenario 6 (reduction of local fleet emissions) ranked first under clean-air priority and produced substantial PM2.5 reductions in Tehran and District 12. Scenario 1 (time-based travel demand management), because of its limited capital requirements and low implementation complexity, was identified as the most suitable immediate action under severe resource constraints. By contrast, Scenario 10 (the public-transport-oriented clean package) and Scenario 11 (the balanced integrated package), despite strong transport and environmental effects, are conditional development options because of their high capital costs, subsidy requirements, and implementation complexity.

The central conclusion is that sustainable transport policy cannot be derived solely by selecting the instrument with the greatest technical effect; it depends on the sequence and conditions under which instruments are implemented. An appropriate policy pathway for Tehran should begin with low-capital, adjustable actions, expand into a complementary and balanced package, and move toward more capital-intensive packages only after financial resources, institutional capacity, and implementation readiness have been secured. The ranking therefore identifies the roles of alternatives – as immediate action, initial package, clean-air pillar, and conditional development package – rather than naming a single universally best policy.

The findings depend on the upstream simulator's structure, scenario definitions, selected criteria, and analytical horizon and should not be treated as deterministic forecasts of real-world implementation effects. Inference is more reliable at the Tehran scale than in District 12; District 12 results should therefore be interpreted mainly in terms of the direction of change and the relative ordering of alternatives. Distributional equity, differences among social groups, and stakeholder acceptance were not entered independently into the matrix due to limitations in microdata. The weighting structures are analytical scenarios of policy preferences rather than preferences directly elicited from all stakeholders. Thus, implementation of the recommendations should be accompanied by pilots, continuous monitoring, and periodic review.

Future research can incorporate distributional equity and social acceptance using microdata, propagate uncertainty in simulator parameters through the ranking stage, extend the analysis to finer spatial and temporal scales, and explicitly model revenue recycling, fleet financing, and life-cycle assessment of electrification. Overall, the framework connects simulated outcomes with the practical constraints of urban decision-making and emphasizes policy combinations and sequencing rather than reliance on a single intervention.

Authors' Contributions

The first author contributed 60%, the second author 20%, and the third and fourth authors each contributed 10%.

Acknowledgments

This research received no independent financial or organizational support.

Conflict of Interest

The authors declare no conflicts of interest in conducting this research.

References

Abbasi, M. T., Alesheikh, A. A., Jafari, A., & Lotfata, A. (2024). Spatial and temporal patterns of urban air pollution in Tehran with a focus on PM2.5 and associated pollutants. *Scientific Reports*, 14, 25150. https://doi.org/10.1038/s41598-024-75678-6

Ahmadi K., Demneh N., Jahandideh M., & Mollaei Y. (2022). Fiscal sustainability in Tehran Municipality: Current situation and suggested reforms. *Urban Economics and Planning*, 3(4): 164–183. [In Persian] https://doi.org/10.22034/uep.2022.367278.1295

Axsen, J., & Long, Z. (2025). Accepting and implementing transport pricing policies for climate: A review of evidence and research gaps. *Ecological Economics*, 238, 108740. https://doi.org/10.1016/j.ecolecon.2025.108740

Banister, D. (2008). The sustainable mobility paradigm. *Transport Policy*, 15(2), 73–80. https://doi.org/10.1016/j.tranpol.2007.10.005

Bayat R., Hassanvand M. S., & Daroudi R. (2020). Economic analysis of the cost of air pollution deaths in Tehran. *Urban Economics and Planning*, 1(3): 188–197. [In Persian] https://doi.org/10.22034/UE.2020.09.03.06

Behzadian, M., Otaghsara, S. K., Yazdani, M., & Ignatius, J. (2012). A state-of-the-art survey of TOPSIS applications. *Expert Systems with Applications*, 39(17), 13051–13069. https://doi.org/10.1016/j.eswa.2012.05.056

Clean Air Act of Iran. (2017). Islamic Consultative Assembly. [In Persian]

Creutzig, F., Roy, J., Lamb, W. F., Azevedo, I. M. L., Bruine de Bruin, W., Dalkmann, H., Edelenbosch, O. Y., Geels, F. W., Grubler, A., Hepburn, C., Hertwich, E. G., Khosla, R., Mattauch, L., Minx, J. C., Ramakrishnan, A., Rao, N. D., Steinberger, J. K., Tavoni, M., Ürge-Vorsatz, D., & Weber, E. U. (2018). Towards demand-side solutions for mitigating climate change. *Nature Climate Change*, 8, 260–263. https://doi.org/10.1038/s41558-018-0121-1

Diakoulaki, D., Mavrotas, G., & Papayannakis, L. (1995). Determining objective weights in multiple criteria problems: The CRITIC method. *Computers & Operations Research*, 22(7), 763–770. https://doi.org/10.1016/0305-0548(94)00059-H

European Commission. (2020). *Sustainable and smart mobility strategy—Putting European transport on track for the future* (COM (2020) 789 final).

European Commission. (2021). *The new EU urban mobility framework* (COM (2021) 811 final).

Goldman, T., & Gorham, R. (2006). Sustainable urban transport: Four innovative directions. *Technology in Society*, 28(1–2), 261–273. https://doi.org/10.1016/j.techsoc.2005.10.007

Haghshenas, H., Vaziri, M., & Gholamialam, A. (2015). Evaluation of sustainable policy in urban transportation using system dynamics and world cities data: A case study in Isfahan. *Cities*, 45, 104–115. https://doi.org/10.1016/j.cities.2014.11.003

Heidarpour A., & Jaberi R. (2022). Sustainable transportation in Iran: Measurement and analysis of related indicators. *Urban Economics and Planning*, 2(4): 247–264. [In Persian] https://doi.org/10.22034/UE.2022.02.04.01

Hosford, K., Firth, C., Brauer, M., & Winters, M. (2021). The effects of road pricing on transportation and health equity: A scoping review. *Transport Reviews*, 41(6), 766–787. https://doi.org/10.1080/01441647.2021.1898488

Hwang, C. L., & Yoon, K. (1981). *Multiple attribute decision making: methods and applications – A state-of-the-art survey*. Springer Science & Business Media. https://doi.org/10.1007/978-3-642-48318-9

Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Mitigation of climate change*. Cambridge University Press. https://doi.org/10.1017/9781009157926

Jafari Shahrestani A., Jahanfar N., & Mirzaei H. (2022). Budget deficit in municipalities: A method for calculation and control based on resource sustainability – Cases of Tehran, Mashhad, Shiraz, and Rasht. *Urban Economics and Planning*, 3(1): 64–75. [In Persian] https://doi.org/10.22034/UE.2022.03.01.05

Mamdoohi A. R., & Hamrang Ghoortlar E. (2021). Impact of congestion pricing policy change on mode choice: The case of Tehran. *Sharif Journal of Civil Engineering*, 37.2(1.1): 13–21. [In Persian] https://doi.org/10.24200/j30.2020.53968.2606

Melkonyan, A., Koch, J., Lohmar, F., Kamath, V., Munteanu, V., Schmidt, J. A., & Bleischwitz, R. (2020). Integrated urban mobility policies in metropolitan areas: A system dynamics approach for the Rhine-Ruhr metropolitan region in Germany. *Sustainable Cities and Society*, 61, 102358. https://doi.org/10.1016/j.scs.2020.102358

Morouji G., Mohammadi Pour H., & Nakhaei E. (2011). Evaluation of sustainable transportation systems using multi-criteria decision-making methods in an uncertain environment: Case study of Tehran. *11th International Conference on Transportation and Traffic Engineering*. [In Persian]

National Laws and Regulations Portal. (2021). *Executive bylaw of Article 8 of the Clean Air Act, with amendments*. [In Persian]

Nieuwenhuijsen, M. J. (2016). Urban and transport planning, environmental exposures and health: New concepts, methods and tools to improve health in cities. *Environmental Health*, 15(Suppl. 1), S38. https://doi.org/10.1186/s12940-016-0108-1

Norouzi M. H., Kameli M. J., Afandizadeh S., & Salehi Sadaghiani J. (2023). Study of the relationships between the components of the urban transportation system evaluation model based on sustainable development indicators (case study: The Tehran metropolitan area). *Urban Economics and Planning*, 4(3): 188–210. [In Persian] https://doi.org/10.22034/uep.2023.413831.1399

Opricovic, S., & Tzeng, G.-H. (2004). Compromise solution by MCDM methods: A comparative analysis of VIKOR and TOPSIS. *European Journal of Operational Research*, 156(2), 445–455. https://doi.org/10.1016/S0377-2217(03)00020-1

Rassafi, A. A., Ostadi Jafari, M., & Javanshir, H. (2014). An appraisal of sustainable urban transportation: Application of a system dynamics model. *International Journal of Transportation Engineering*, 2(1), 47–66. https://doi.org/10.22119/ijte.2014.6708

Rupprecht Consult. (2019). *Guidelines for developing and implementing a sustainable urban mobility plan* (2nd Ed.). European Commission.

Salarvandian, F., Dijst, M., & Helbich, M. (2017). Impact of traffic zones on mobility behavior in Tehran, Iran. *Journal of Transport and Land Use*, 10(1), 965–982. https://doi.org/10.5198/jtlu.2017.1087

Selmoune, A., Cheng, Q., Wang, L., & Liu, Z. (2020). Influencing factors in congestion pricing acceptability: A literature review. *Journal of Advanced Transportation*, 2020, 4242964. https://doi.org/10.1155/2020/4242964

Shahbazi, H., Hassani, A., & Hosseini, V. (2019). Evaluation of Tehran clean air action plan using emission inventory approach. *Urban Climate*, 27, 446–456. https://doi.org/10.1016/j.uclim.2019.01.002

Shahbazi, H., Reyhanian, M., Hosseini, V., & Afshin, H. (2016). The relative contributions of mobile sources to air pollutant emissions in Tehran, Iran: An emission inventory approach. *Emission Control Science and Technology*, 2, 44–56. https://doi.org/10.1007/s40825-015-0031-x

Shahbazi M., Fathi M. R., & Jesri N. (2021). Evaluation and prioritization of urban transport projects with a human-centered development approach using fuzzy AHP and fuzzy TOPSIS. *Geography and Regional Planning*, 11(42): 661–677. [In Persian] DOR: 20.1001.1.22286462.1400.11.2.34.4

Shepherd, S. (2014). A review of system dynamics models applied in transportation. *Transportmetrica B: Transport Dynamics*, 2(2), 83–105. https://doi.org/10.1080/21680566.2014.916236

Small, K. A., & van Dender, K. (2007). Fuel efficiency and motor vehicle travel: The declining rebound effect. *The Energy Journal*, 28(1), 25–52. https://doi.org/10.5547/ISSN0195-6574-EJ-Vol28-No1-2

Suryani, E., Hendrawan, R. A., Adipraja, P. F. E., & Indraswari, R. (2020). System dynamics simulation model for urban transportation planning: A case study. *International Journal of Simulation Modelling*, 19(1), 5–16. https://doi.org/10.2507/IJSIMM19-1-493

Tahamipour Zarandi M., & Moghise M. (2022). Social cost-benefit analysis of replacing defective catalytic converters in Tehran's light vehicles to reduce air pollution. *Urban Economics and Planning*, 3(1): 104–120. [In Persian] https://doi.org/10.22034/UE.2022.3.01.08

Tahsiri, A., & Arab, M. (2023). A system dynamics model for a holistic analysis of urban NOx emissions: A case study of Tehran, Iran. *Environment, Development and Sustainability*, 25, 7299–7323. https://doi.org/10.1007/s10668-022-02323-5

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development* (A/RES/70/1).

United Nations Department of Economic and Social Affairs. (2019). *World urbanization prospects: The 2018 revision*. United Nations.

United Nations Economic and Social Commission for Asia and the Pacific. (2020). *Assessment of urban transport system in Tehran*.

United Nations Human Settlements Programme. (2022). *World cities report 2022: Envisaging the future of cities*.

Vafa-Arani, H., Jahani, S., Dashti, H., Heydari, J., & Moazen, S. (2014). A system dynamics modeling for urban air pollution (case study: Tehran, Iran). *Transportation Research Part D: Transport and Environment*, 31, 21–36. https://doi.org/10.1016/j.trd.2014.05.016

Vickrey, W. S. (1969). Congestion theory and transport investment. *American Economic Review*, 59(2), 251–260.

World Health Organization. (2021). WHO global air quality guidelines: Particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

Zavadskas, E. K., & Turskis, Z. (2011). Multiple criteria decision making (MCDM) methods in economics: An overview. *Technological and Economic Development of Economy*, 17(2), 397–427. https://doi.org/10.3846/20294913.2011.593291