



MULTI-CRITERIA COMPARATIVE ASSESSMENT OF URBAN TRANSPORT SOLUTIONS IN MODERN CITIES

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Abstract. *This study compares seven alternative directions of urban transport policy: bus rapid transit (BRT), metro and light rail, congestion pricing, intelligent transport systems (ITS), walking and cycling infrastructure, bus electrification, and Mobility as a Service (MaaS). The alternatives are evaluated using a five-criterion, 1-10 scoring scale and a weighted-sum multi-criteria decision analysis model. The author's analytical scenario assigns priority to capacity and environmental outcomes while also accounting for implementation speed, cost-effectiveness, and social acceptability. BRT ranks first with a weighted score of 7.70, followed by walking and cycling infrastructure with 7.30. An equal-weight control scenario preserves the same two leading positions. The findings indicate that the alternatives should be treated as a complementary policy portfolio rather than as mutually exclusive options. On this basis, the study proposes a phased reform model that integrates short-, medium-, and long-term measures. The assessment is diagnostic and should be recalibrated using local data and stakeholder preferences before it is applied to a specific city.*

Keywords: urban transport, multi-criteria decision analysis, BRT, intelligent transport systems, active mobility, electric bus, MaaS, sustainable mobility.

1. Introduction

According to the United Nations' 2025 estimates, 45% of the world's population lives in cities and 36% in towns and semi-dense urban areas, whereas the share living

in cities was only 20% in 1950 [1]. The spatial concentration of population and economic activity intensifies road congestion, travel-time unreliability, local air pollution, and inequality in access to transport services. Consequently, transport policy should move beyond the construction of additional roads or the selection of a single transport mode and should instead integrate public transport, active mobility, demand management, digital services, and land-use planning [2, 11].

In a modern city, the effects of an intervention on capacity, environmental performance, implementation time, cost, and social acceptability rarely move in the same direction. Metro systems, for example, provide high passenger capacity but require long construction periods and substantial capital expenditure. Congestion pricing can be implemented more rapidly, yet it may be difficult to secure public acceptance. Such trade-offs call for the use of multi-criteria methods in transport decision-making [8-10].

The purpose of this study is to compare seven alternative solutions to urban transport problems within a common evaluation framework, identify their relative strengths and limitations, and develop a phased implementation model. The study's scientific and practical contribution lies in assessing all alternatives on the same 1-10 scale, conducting a simple robustness check for changes in criterion weights, and linking the results to indicative implementation horizons.

2. Literature Review and Policy Context

The infrastructure, governance, and technological instruments of transport policy are complementary. BRT combines dedicated right-of-way, level boarding, operational control, and service-quality standards within a single system [3]. Walking and cycling infrastructure can be delivered relatively quickly, shift a proportion of short trips away from private cars, and improve first- and last-mile connections to public transport [4]. Bus electrification reduces local tailpipe emissions, but it requires joint assessment of vehicles, charging infrastructure, the electricity grid, route profiles, and total life-cycle costs [5].

Congestion pricing and parking policy manage demand for car travel, while ITS improves the efficiency of existing infrastructure through real-time information, adaptive traffic-signal control, and public-transport priority. MaaS aims to integrate different operators, routes, information, and payment services through a single digital interface. However, it is not an independent infrastructure solution; rather, it acts as an integrator of the existing transport system [6, 7]. In local planning, data on passenger flows, route networks, and service quality provide the essential evidence base for decision-making [12].

3. Materials and Methods

The evaluated alternatives are BRT, metro/light rail, congestion pricing, ITS, walking and cycling infrastructure, bus electrification, and MaaS. Five criteria are applied: K1 - capacity impact; K2 - environmental benefit; K3 - implementation speed; K4 - cost-effectiveness; and K5 - social acceptability. For K4, a high score does not simply indicate low cost; it represents a strong outcome relative to the resources required. All five criteria are therefore interpreted as benefit criteria to be maximized.

The criterion weights are set at 0.25 for capacity impact, 0.25 for environmental benefit, 0.15 for implementation speed, 0.20 for cost-effectiveness, and 0.15 for social acceptability. These weights represent an analytical scenario in which mobility and environmental outcomes are prioritized in urban transport policy. The total score for each alternative is calculated using the weighted-sum model:

$$S_j = \sum_{i=1}^5 w_i x_{ij}, \quad (1)$$

where S_j is the overall score of alternative j ; w_i is the weight of criterion i , with the weights summing to 1; and x_{ij} is the score of alternative j on criterion i , measured on a scale from 1 to 10. The scores were developed by the authors through a comparative synthesis of international methodological guidance and scholarly literature [2-10]. The results should therefore be interpreted as an initial diagnostic scenario rather than as a final investment decision for a specific city.

For consistent interpretation, scores of 1-3 are classified as low, 4-6 as moderate, 7-8 as high, and 9-10 as very high. The capacity criterion captures passenger-carrying capacity and the potential to shift trips away from private cars. The environmental criterion reflects effects on emissions and active mobility. The implementation-speed criterion covers planning, procurement, and construction time. The cost criterion reflects outcomes relative to total costs, while the social criterion represents convenience, coverage, and public acceptability.

Alternatives are ranked in descending order of S_j . Alternatives with identical overall scores share a rank range. In addition to the main calculation, a control scenario assigns an equal weight of 0.20 to every criterion in order to test whether the choice of weights affects the two leading positions.

Table 1. Criterion scores, overall weighted scores, and rankings of urban transport solutions

Solution	K1: Capaci ty (0.25)	K2: Env. benefit (0.25)	K3: Speed (0.15)	K4: Cost efficiency (0.20)	K5: Accepta bility (0.15)	Scor e	Ra nk
BRT	9	7	7	8	7	7.70	1
Walking/cycling infrastructure	4	9	8	9	7	7.30	2
Congestion pricing	6	7	8	9	4	6.85	3-5
Intelligent transport systems	6	6	8	8	7	6.85	3-5
Bus electrification	5	10	6	5	8	6.85	3-5
Metro/light rail	10	8	3	3	8	6.75	6
MaaS platform	6	6	7	7	6	6.35	7

Note: All criteria are interpreted as benefit criteria; a higher score indicates a more favorable result. The 1-10 scores constitute the authors' analytical scenario based on a synthesis of the literature.

4. Results and Discussion

In the weighted calculation, BRT ranks first with 7.70 points, followed by walking and cycling infrastructure with 7.30 points. Congestion pricing, ITS, and bus electrification each receive 6.85 points. Although their overall scores are identical, these measures have different functions and implementation requirements. Metro/light rail scores 6.75, while MaaS receives 6.35. Figure 1 presents the solutions in descending order of their weighted score.

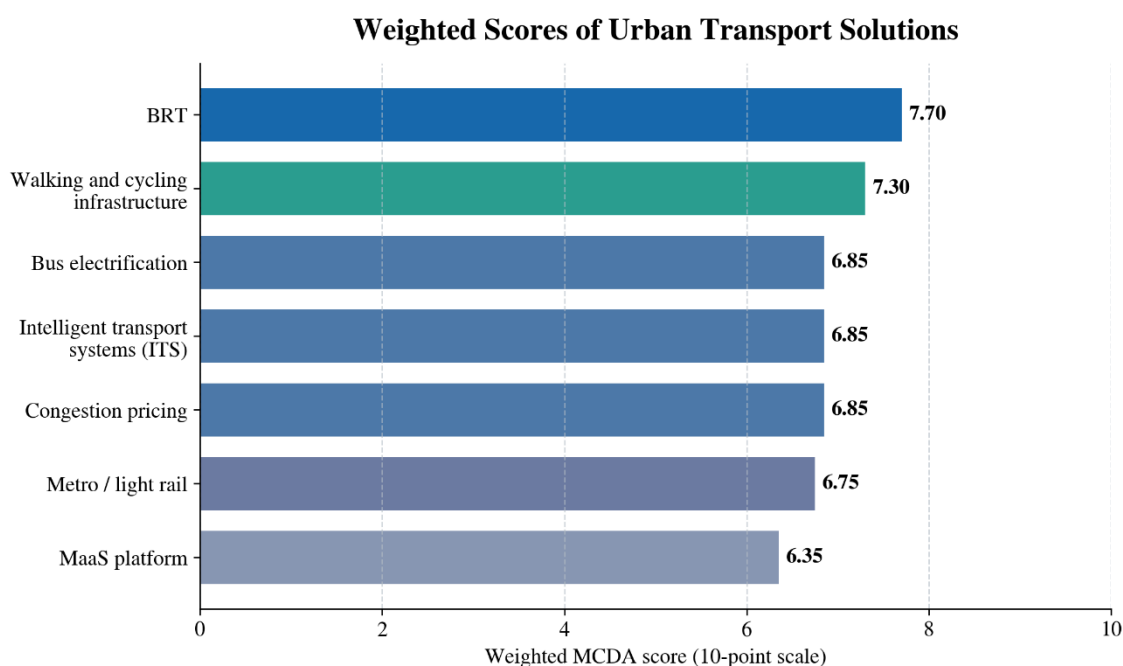


Figure 1. Ranking of urban transport solutions by weighted overall score.

BRT's leading position reflects its potential to combine high capacity with a shorter delivery period and lower capital cost than metro. This result, however, depends on the provision of dedicated lanes, high-quality stations, and stable operational management [3]. Active mobility performs strongly on environmental benefit and cost-effectiveness. Although its capacity score is lower, it offers system-wide benefits for short trips and connections to public transport [4].

The three solutions scoring 6.85 are not substitutes for one another. Congestion pricing is a demand-management and revenue-generation instrument; ITS is an operational tool for managing the existing network; and bus electrification is a

technological modernization measure for vehicle fleets and energy infrastructure. Metro may deliver very high capacity and substantial social benefits, but its feasibility must be justified by demand density, construction risk, and long-term financing. Although MaaS has only moderate direct effects on capacity and the environment, it can provide a strategic platform that integrates the other measures into a coherent user experience [6].

Criterion Profiles of Four High-Scoring Solutions

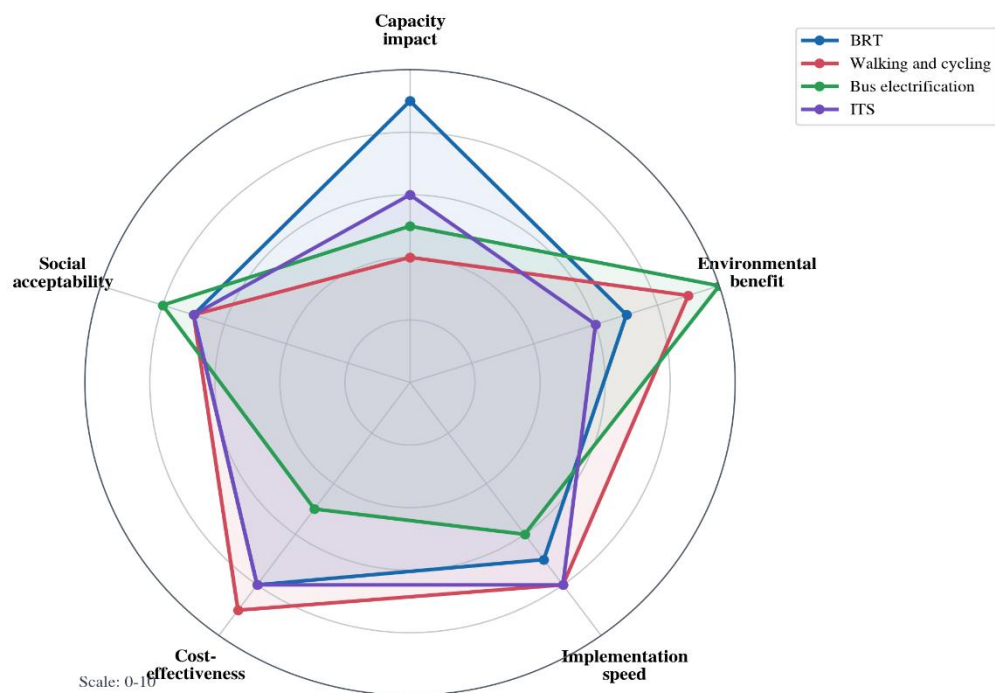


Figure 2. Criterion profiles of the four selected high-scoring solutions.

The profile analysis in Figure 2 reveals differences concealed by the overall scores. BRT is comparatively balanced across the five criteria. Walking and cycling infrastructure performs particularly well on environmental benefit, implementation speed, and cost-effectiveness. Bus electrification scores highly on environmental and social criteria but is constrained by cost-effectiveness. ITS performs consistently on implementation speed and cost-effectiveness. The ranking should therefore be used to design a complementary portfolio rather than to select a single stand-alone solution.

As a robustness check, an equal weight of 0.20 is assigned to every criterion. Under this control scenario, BRT scores 7.60, walking and cycling infrastructure 7.40, ITS 7.00, congestion pricing and bus electrification 6.80 each, and metro/light rail and MaaS 6.40 each. The first two positions remain unchanged. Within the current score matrix, the leading alternatives are therefore robust to this simplified change in weights. A full sensitivity analysis would nevertheless require local data and stakeholder-derived weights.

5. Phased Reform Model

The comparative assessment supports implementing the solutions as a three-stage policy portfolio. In the short term (0-2 years), cities can improve their data systems and launch smart-signal, parking-management, and demand-management pilots. In the medium term (2-5 years), they can expand BRT, safe walking and cycling networks, and MaaS integration. In the long term (5-15 years), they can implement demand-justified metro or light-rail projects and phased bus electrification. These time horizons are indicative and should be adapted to each city's financial, institutional, and spatial conditions.

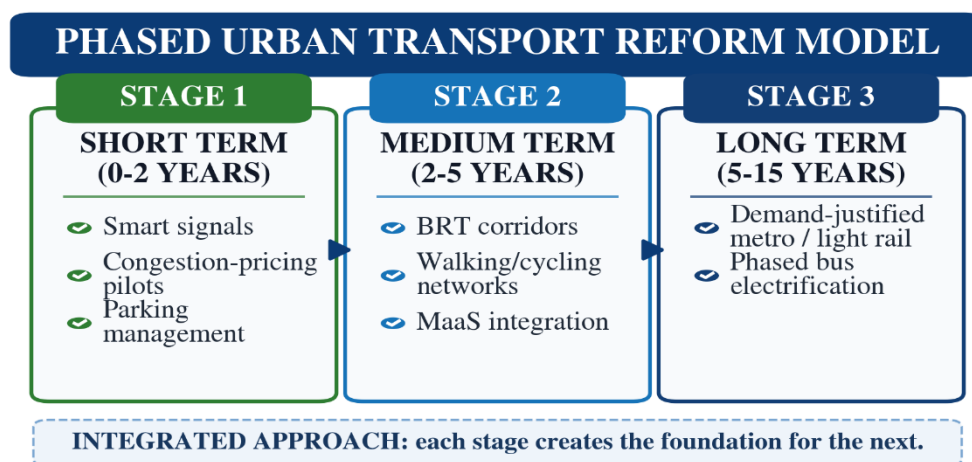


Figure 3. Short-, medium-, and long-term model for urban transport reform.

6. Recommendations and Limitations

The following measures are recommended for translating the MCDA results into practical decisions:

- establish baseline indicators for passenger flows, travel time, service reliability, emissions, road crashes, and transport costs before conducting the assessment;
- recalibrate criterion weights and scores through a transparent process involving municipal authorities, transport operators, passengers, businesses, and experts;
- design BRT, active mobility, and ITS as components of an integrated corridor program rather than as separate projects;
- assess total cost of ownership, charging schedules, depot requirements, grid capacity, and battery life cycles before procuring electric buses [5]; and
- develop MaaS around integrated fares, open-data standards, and passenger-protection mechanisms while maintaining priority for public transport [6].

The principal limitation of this study is that the scores are not derived from observed data for a specific city or from a formal expert survey. They represent an author-defined scenario informed by a synthesis of the literature. The resulting ranking is therefore not a universal standard. Future research should apply methods such as the Analytic Hierarchy Process (AHP), TOPSIS, or PROMETHEE; assess agreement among experts; and calculate uncertainty intervals and a broader range of weight scenarios [8, 9].

7. Conclusion

The multi-criteria comparative assessment demonstrates that urban transport problems cannot be solved through a single technology. In the analytical scenario developed here, BRT and walking and cycling infrastructure occupy the first two positions, and the equal-weight robustness check preserves this order. Congestion pricing, ITS, and bus electrification receive the same overall score but perform different functions. Metro and MaaS complement the long-term portfolio as high-capacity infrastructure and an integration platform, respectively.

The most suitable approach is to combine short-term management measures with medium-term BRT and active-mobility infrastructure, while linking long-term rail and electrification projects to reliable demand forecasts and sound financial justification. The proposed model provides a transparent basis for comparing policy options, but it must be recalculated using local indicators and stakeholder preferences before application in a particular city.

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