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A stratified data driven decision making framework for transport policy evaluation

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1 Introduction

Transport policies are set by governments to shape the long-term plans of cities and regions. They impact not only mobility patterns, accessibility, sustainability, but also economic competitiveness (Sogbe et al., 2025, Moslem et al., 2024). This is to say, the cumulative impact of transport policy decisions determines how an urban area succeed in the future (Bahman et al., 2025). However, the task of designing and evaluating such policies can be complex. Executives and senior managers making such decisions face multiple, often conflicting objectives. They must balance reducing congestion, cutting emissions, ensuring social equity, maintaining economic efficiency, and safeguarding public health.

The literature in the context of transport policy making provides traditional decision-making tools. One of the prevalent tools is Cost–benefit analysis (CBA); offering a structured way to monetise costs and benefits and compare alternatives (van Wee et al., 2023). Multi-criteria decision analysis (MCDA) provides a more flexible framework (Bouraima et al., 2024). MCDA allows for both quantitative and qualitative criteria to be considered without transforming all impacts into monetary terms (Moslem, 2024). Scenario planning has also gained popularity (Louen et al., 2023). It is a way to explicitly acknowledge uncertainty and explore a range of possible futures (Tori et al., 2025). Each of these has strengths and limitations. CBA struggles with non-monetary values and can be criticised for oversimplifying complex parameters with social and environmental impacts. MCDA is adaptable but it can be criticised for being static (Asadabadi, 2022, Asadabadi, 2023, Maghsoodi and Asadabadi, 2025). Scenario planning recognises uncertainty; however, it is often highly subjective and lacks a structured, quantitative evaluation framework.

Given these, the literature gap can be summarised as below: while transport policy decisions have a long-term nature and are subject to uncertainty, existing approaches either do not account for integrating uncertainty into the evaluation process or else fail to provide a well-structured and practitioner-friendly framework to evaluate policies. This paper is focused on addressing this research gap by developing a stratified decision-making framework. The proposed framework combines the strengths of MCDA and scenario planning. By doing so, a structured, scenario-based approach is introduced in which criteria weightings can have different sets of weightings to reflect a range of possible futures. The proposed framework provides decision makers with a robust and reliable tool which captures the dynamic nature of transport systems.

This study does not propose an entirely new mathematical framework. Instead, its contribution lies in the practical integration of existing concepts into an innovative framework for evaluating real transport policy problems. The framework is easy to apply for practitioners and robust to small errors in inputs. It is particularly useful to group decision-making, where it can help build consensus from diverse stakeholder perspectives. The methodology is illustrated through a conceptual case study in Perth, Western Australia to demonstrate its step-by-step application.

2 Methodology

The proposed stratified decision-making framework is structured into two phases, and each phase contains five steps. The first phase is the identification phase that is more focused on the decision context, policy alternatives, evaluation criteria, and possible future events. This is followed by the computational phase to estimates values related to event and scenario likelihoods. Then these values are used to compute final rankings.

Identification phase

1. Decision context and objectives: Define the decision problem and objectives. In the Perth case, objectives were identified to be congestion reduction, emissions reduction, social equity, economic efficiency, and political feasibility.
2. Policy alternatives: Identify a set of policy options to be alternatives in the decision framework. In our case, four were considered as follows: congestion charge, fuel tax increase, transit fare reductions, and public transport investment.
3. Criteria: Identify and establish evaluation criteria aligned with objectives. In our case, these included environmental impact, congestion relief, economic efficiency, social equity, and political acceptability.
4. Events: This step is to identify possible future events that could affect criteria importance weights or alternative performance. In our case study, three events were considered namely: stricter environmental regulation, economic recession, and rapid population growth.
5. Scenarios: This step is to structure events into forming a set of scenarios. With three events, eight scenarios were structured from the occurrence of no event to the occurrence of all three together.

Computational phase

6. Likelihood estimation: This step is to estimate probabilities of events and scenarios. We recommend using expert judgment. For demonstration purpose, events were assumed independent.
7. Alternative–criteria matrix: Each alternative is scored against each criterion. A scale of 1 to 10 was used to compare the performance of alternatives with respect to different criteria.
8. Criteria–scenario matrix: This step is to determine how criteria weightings change under different scenarios. For example, under recession, economic efficiency gains importance; under stricter regulation, environmental impact dominates.
9. Overall criteria weightings: In this step, scenario-specific weightings are integrated with scenario probabilities in order to calculate the overall criteria importance.
10. Final rankings: Finally, by multiplying criteria weightings by alternative scores, the overall performance and rank policies are calculated.

3 Main findings

A conceptual case study of Perth, Western Australia was used to demonstrate the framework. Perth has over 2.2 million residents with a multimodal transport system. The case study illustrates dynamicity of the evaluation of policy alternatives under uncertainty.

Policy alternatives: The alternatives we had in this case are as set out below.

- Transit fare reductions: Subsidising public transport fares to encourage mode shift. This improve equity while reducing fare revenue.
- Public transport investment: Expanding infrastructure and services. Long-term benefits for emissions and significant upfront funding.
- Congestion charge: Levying fees on vehicles entering the city centre during the peak hours. Concerns were related to equity problem for low-income drivers.

- Fuel tax increase: Raising fuel taxes not only to discourage car use but also to generate revenue. This was politically sensitive.

Evaluation criteria

Five criteria were used in this case study namely: environmental impact, economic efficiency, congestion relief, social equity, and political feasibility.

Future events and scenarios

Three events were identified: stricter environmental regulation, economic recession, and rapid population growth. The consideration of these three events results in forming eight scenarios, ranging from no event to all three occurring simultaneously.

Results

- **Dynamic weighting**: Criteria importance changed under different scenarios. For example, during a recession, economic efficiency became more important. Under stricter regulation, environmental impact held the highest value.
- **Alternative performance**: Public transport investment consistently scored well on environmental and equity criteria but due to high cost underperformed under recession. Congestion charging performed quite well on congestion and revenue but was subject to equity concerns. Fuel tax increases while being effective environmentally were found to be politically risky. Transit fare reductions can enhance equity but then they may risk financial sustainability.
- **Robustness**: The framework produced stable rankings. The inputs were changed to a reasonable degree and the output data demonstrated resilience.

4 Discussion

The stratified decision-making framework contributes to the literature by integrating MCDA and scenario planning. Compared to common MCDA approaches, it offers a clear, step-by-step process for integrating uncertainty into criteria weighting. It also does not suffer from unstructured subjective scenario planning approach. By contrast it provides a quantitative evaluation framework. The result is a framework that is both rigorous and accessible.

Managerial implications include the ability to:

- Incorporate uncertainty directly into evaluation. This can reduce human optimism bias.
- Provide a transparent, stepwise process that is easy to follow for practitioners.
- Facilitate consensus in group decision-making where conflicts are qualified and discussed.
- Enhance robustness even with imperfect inputs.

The main limitation of this study was the reliance on expert judgment for event probabilities and scenario weightings. Future research could apply predictive modelling to estimate these values more precisely. Overall, the framework is straightforward for practitioners and enhances effective decision making in policy evaluation.

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