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# Road network pricing models for travel demand management: Australian perspective

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## Abstract

This paper explores the role of road network pricing in managing travel demand and fostering sustainable transport practices amid growing calls for road pricing in Australia. Through a rigorous systematic literature review, this research first consolidated the empirical evidence on road network pricing's efficacy and explored methodologies for analysing its impacts. The review findings were used to inform a survey of public opinion which was conducted in Melbourne and Sydney. These surveys revealed good public support for road pricing initiatives, particularly when coupled with enhancements to public transport services. Logit and machine learning road pricing choice models were then developed using the survey responses, and used to understand the factors influencing road user acceptance and willingness to pay road pricing fees. Travel behaviour indicators like trip frequency, trip purpose, and mode of travel were found to influence public acceptance of road pricing, with respondents in both cities showing similar support for allocating the road pricing revenue towards public transport improvements. Finally, using traffic simulation methodologies, the research evaluated the effectiveness of road pricing strategies using a dynamic transport model for Melbourne. By simulating different scenarios, the case study for Melbourne assessed the potential impacts of cordon pricing on traffic patterns, emissions, and transport network efficiency. The findings showed potential reductions of 10 percent in traffic volumes, and 10 percent reduction in emissions within the proposed pricing zone under a $10 cordon pricing scheme. As a result, it was found that shifting 12 percent of drivers to public transport could enhance network performance by up to 40 percent. Overall, the paper offers practical contributions on the topic, bridging knowledge gaps and offering insights for successful implementation of road pricing schemes in Australia.

**Keywords**: Road pricing; transport taxation reform; transport modelling; stochastic route choice experiment; artificial neural network modelling; behavioural surveys

## 1 Introduction

Cities around the world continue to face major transport challenges including traffic congestion and emissions from increased reliance on low-occupancy private vehicles. Recent studies indicate that post-COVID car usage has returned, and in some cases has exceeded, pre-COVID levels (Munir et al., 2023, Beck and Hensher, 2020). For example, a recent survey in Sydney (Du et al., 2024) showed that driving is now the preferred mode of transport for 58% of respondents compared to 53% pre-COVID which tends to exacerbate traffic congestion issues. This has prompted renewed interest in travel demand management approaches that reduce the need for travel and limit the number of cars in congested areas particularly in central city and commercial hubs (Dia, 2017). One approach that has been considered in the past is road network pricing, including congestion charging, which if well-implemented can be

an effective approach for managing travel demand and promoting low carbon mobility (Shatanawi et al., 2022).
Congestion pricing is particularly an effective instrument to address congestion externalities and other transport challenges (Marazi et al., 2022). These schemes aim to reduce traffic congestion, lower greenhouse gas emissions, and at the same time generate revenue to support public transport services and low-carbon mobility infrastructure development (Zheng et al., 2014). In this strategy, a surcharge is applied on cars that enter certain urban centres or congested areas. Road pricing, on the other hand, is a broader road-user pay scheme that is intended to manage demand and is also seen as a transport taxation reform that charges drivers a fee to drive on public roads. This would be used instead of relying on the current vehicle registration, fuel excise and licensing fees (Munir et al., 2021). In the context of travel demand management, road network pricing thus refers to wide-ranging strategies aimed at managing private vehicle travel, reducing road congestion, and enhancing the performance of the road network. If well-implemented, these schemes discourage low-occupancy private vehicle use, influence sustainable travel behaviour in the long-term, and promote sustainable transport modes. Implemented at various spatial and temporal levels, they can lead to positive mobility outcomes and improve accessibility (Gu et al., 2018b). Renewed interest in road network pricing, including in Australia, is driven by a number of factors such as declining revenue from fuel taxes (**Figure 1)**, which has been exacerbated in recent years by the rise of electric and fuel-efficient vehicles (Bureau of Infrastructure and Economics, 2023).

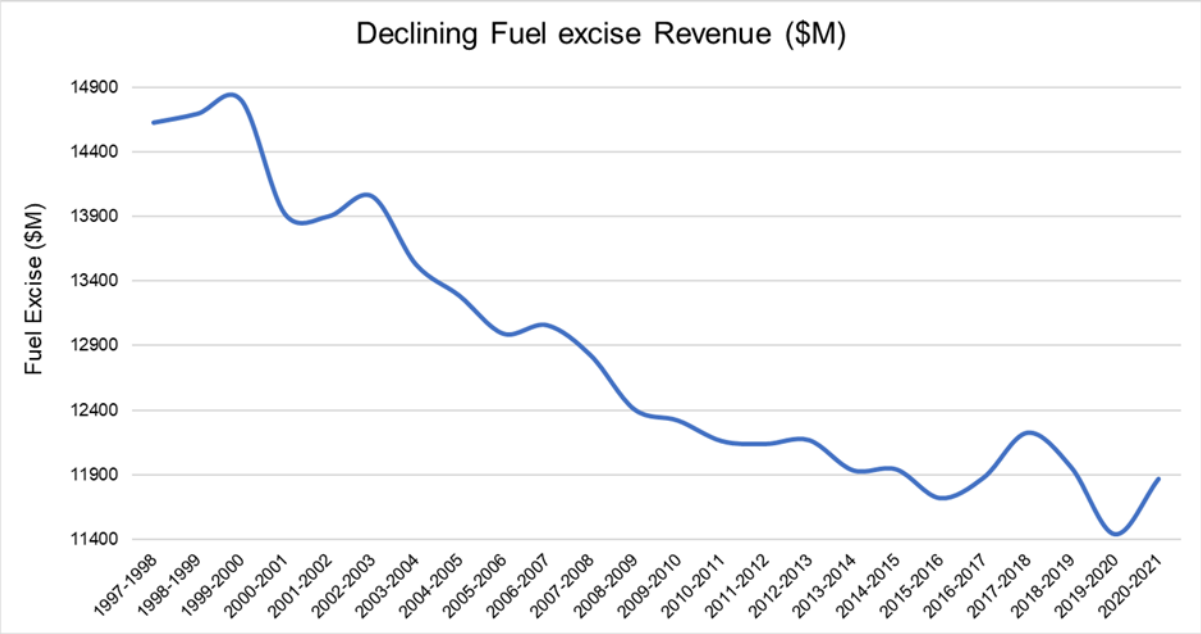


**Figure 1: Fuel excise revenue in Australia**

However, gaps exist in prior research, particularly regarding incorporating real-world behavioural data into modelling methods and generating evidence on effectiveness and public acceptance of road pricing. The work reported in this paper is part of a research study that aimed to address these gaps by developing and assessing transport pricing models that are applicable in Australia. The research involved development of quantitative transport models, Logit models, and Artificial Neural Network (ANN) models using local public surveys to create reliable simulation models for testing pricing strategies. The findings can help policy directions on road transport taxation reform informed by public opinion regarding the necessity and equitable implementation of road pricing.

# 2 Systematic literature review

The research started by adapting the Systematic Literature Review (SLR) methodology including identifying, evaluating, interpreting and describing the existing body of knowledge about road network pricing with emphasis on its effectiveness as a travel demand management strategy. The research follows guidance from seminal articles on SLR to formulate robust and reproducible research. This section provides a brief summary of road network pricing studies clusters identified through the SLR including public acceptance, evaluation methodologies and modelling of impacts of various pricing solutions.

## 2.1 Acceptability

Public acceptability for road pricing policies has been widely studied in the current literature as it is a crucial factor in the success of this policy reform. Researchers argued that governments have faced considerable opposition to road pricing due to privacy, complexity, equity, and uncertainty about the benefits of the scheme (Munir et al., 2021). Other reasons include administrative issues, lack of trust in government, high installation costs, public attitudes towards new policies, political acceptance, and complexity of dynamic charging systems. Wherever a road pricing scheme was implemented, trialled, or even proposed, it has faced public resistance. In 1983 Hong Kong government envisaged launching a road user charge and trialled an electronic road pricing scheme until 1985. The scheme was found to be technically sound and feasible, however, this proposal was abandoned due to strong public opposition. Similarly, and after years of planning and false starts, New York city's congestion pricing was recently abandoned (Templeton, 2024) after also previously facing strong political opposition by non-governing parties (Marazi et al., 2022). The Edinburgh cordon pricing scheme was also rejected by 75 percent of the voters, the Manchester proposal was turned down due to 79 percent opposition, and Birmingham also faced strong public opposition for its proposed road pricing schemes (Lehe, 2019).

## 2.2 Modelling of impacts

A simulation study conducted for Budapest, Hungary explored the impacts of static and dynamic road pricing schemes. The results showed that dynamic pricing outperforms the static pricing in terms of overall social benefits, while the static pricing scheme was more successful in mixed traffic scenario. Among all scenarios tested, the link-based scheme provided best results and generated maximum amount of revenue (Shatanawi et al., 2022). In New York City, a traffic simulation study investigated the impacts of a proposed cordon-based pricing scheme. Various pricing scenarios were simulated, with charges ranging from USD 5 to USD 20 for entry into the city. The results demonstrated significant reductions in trips to and from the central business district, increased public transport usage, decreased single-occupancy vehicles and taxi traffic, reduced emissions particularly particulate matter, and decreased travel delays for all modes of transport (Baghestani et al., 2020). In Zurich, a dynamic cordon pricing scheme was modelled to determine an optimal charge for a congested network. The study proposed a cordon pricing area with dynamic charging ranging from EUR 1 to EUR 4, operational during peak hours. High charging scenarios resulted in reduced traffic congestion within the cordon area, with slight increases in traffic density in neighbouring zones (Zheng et al., 2012).

## 2.3 Implementation impacts

Congestion pricing has been implemented in several jurisdictions around the world such as Singapore, London, Stockholm, Milan, Gothenburg, Oregon, Vancouver and New York. The benefits reported are compelling. In the twelve years since the scheme started in London, traffic congestion reduced by 10 percent, which included 34 percent drop in private cars entering the city centre, and 28 percent increase in the number of cyclists accessing the city (Lehe, 2020). The scheme also reduced emissions by 16 percent within the study area, amounting to a reduction of 30,000 tonnes of carbon monoxide annually. A road safety study also found that the scheme resulted in reducing traffic collisions by 40 percent over a 10-year

period between 2000 and 2010. London's congestion pricing scheme also raised more than $300 million per year in revenue which was invested in public transport and active transport infrastructure. London's Ultra Low Emission Zone (ULEZ) was also expected to remove more than 15,000 high emitting vehicles from London roads (TfL, 2023). Stockholm's congestion pricing scheme reduced peak traffic by 20 percent and increased public transport ridership by 9 percent. In the city's densely populated centre, emissions decreased by 14 percent. The scheme generated an estimated $500,000 daily revenue which was reinvested in expanding bike lanes and new dedicated bus lanes. Sweden's Gothenburg scheme was also a success and reduced congestion by 12 percent during peak hours and shifted a large number of private car users to public transport (Eliasson, 2016). Singapore's congestion pricing scheme, which was established in 1975 and upgraded to Electronic Road Pricing (ERP) in 1998, was found to have reduced congestion by 45 percent, road crashes by 25 percent, as well as reduced traffic volumes entering the central business district by 15 percent (Agarwal and Koo, 2016). These success stories provide unique insights into the pathways for implementation and demonstrate that road pricing can be effective in reducing congestion, lowering emissions, improving amenity, and addressing inequity in transport taxation systems (Dia, 2017, Eccleston and Marsh, 2011, Hensher and Puckett, 2007).

# 3 Stated preference survey

This research included a stated preference questionnaire survey to understand public attitudes towards road pricing in Australia. The online survey was informed by an extensive literature review on public acceptance and willingness to pay for road pricing policies to develop the survey design. The survey aimed to understand public perspectives on road pricing as a strategy for managing travel demand, was anonymous and took approximately 15-20 minutes to complete. The survey covered household and socio-demographic information, travel patterns (reflect only on recent travel patterns since January 2022), mode and route choices, opinions on congestion levels, travel times, acceptance of road pricing schemes, preferences for revenue usage, and willingness to pay. In each question, respondents were provided with a range of options to choose their answers. In terms of charge types, they were presented with cordon-based, distance-based charge, or a combination of both. They were also informed that the revenue generated from congestion charges would be used to improve multi-modal transport services. Ethics approval was obtained from Swinburne University Human Research Ethics Committee. The survey was conducted in Melbourne in April 2022 and Sydney in late November to early December 2022.

## 3.1 Overview of survey results

The survey gathered a total of 373 responses for Melbourne and 556 for Sydney (**Table 1**), with both surveys sharing similar demographics. The majority of respondents in both cities (95 percent in Melbourne, 90 percent in Sydney) owned personal vehicles and preferred driving to their work or study locations. However, car usage was higher in Melbourne (70 percent) compared to Sydney (61 percent), while public transport usage was more prevalent in Sydney (28 percent) than Melbourne (16 percent).

**Table 1: Basic survey strata**

| City | Survey Duration | Sample | Gender | Vehicle Ownership | Preferred Mode of Transport |
|---|---|---|---|---|---|
| **Melbourne** | 5-10 April 2022 | 373 | M=165<br>F=205<br>Other=3 | Yes=328<br>No=17<br>No license=28 | Car=223<br>PT=49<br>Bike, walk, e-bike, scooter, bicycle & ride share = 101 |
| **Sydney** | 24 Nov-5 Dec 2022 | 556 | M=297<br>F=256<br>Other= 3 | Yes= 467<br>No= 54<br>No license= 35 | Car= 339<br>PT= 154<br>Bike, walk, e-bike, scooter, bicycle & ride share = 63 |
| **Total** | - | 929 | M=462<br>F=461<br>Other=6 | Yes=795<br>No=71<br>No license=63 | Car=562<br>PT=203<br>Bike, walk , e-bike, scooter, bicycle & ride share =164 |

The survey was designed to include dependent variables indicating the extend of public support for road user charges. The independent variables included three categories: (i) sociodemographic profiles, including age, gender, education, job, income, and profession; (ii) travel behaviour, encompassing preferred mode of travel, travel frequency, trip purpose, daily travel distance, work from home preferences, and departure time; and (iii) preferences regarding the usage of revenue generated from road pricing schemes, such as supporting public transport service improvements, reducing public transport fares, and enhancing infrastructure for multimodal transport. Additionally, the survey captured data on congestion levels on respondents' usual routes and their knowledge about road pricing's benefits in reducing traffic congestion and emissions.

### *3.1.1 Public acceptance and support for road pricing*

The results from the behavioural survey showed that around one-third of respondents in Melbourne supported congestion pricing as a travel demand management strategy. The level of support was higher in Sydney (around 40 percent) as shown in **Figure 2**. An equal percentage of around 32 percent of travellers from Melbourne and Sydney opposed road pricing, citing concerns that they were already paying considerable fees in the form of other taxes and did not have confidence in government decision making.

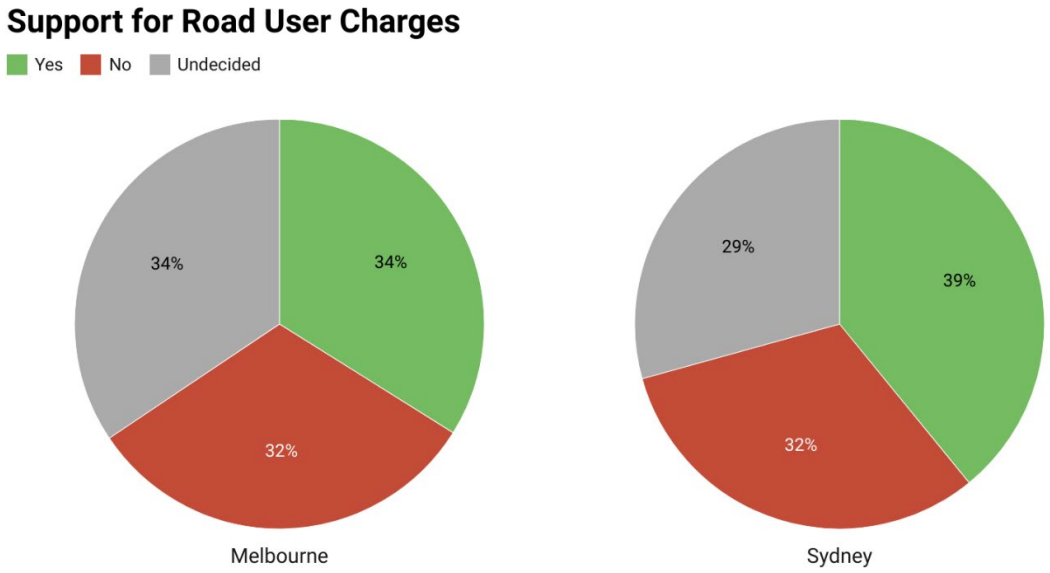


**Figure 2: Support for road user charges**

### *3.1.2 Revenue allocation benefits and public support*

The percentage of respondents who would support congestion pricing increased notably when they were informed that the revenue generated from congestion charges would be used to improve multi-modal transport services (**Figure 3**).

Previous research had considered the uncertainty about revenue allocation from congestion charging schemes as a prominent cause for low public acceptance for road pricing (Gu et al., 2018a), and that a key benefit of road pricing is the opportunity to use the revenue in subsidising the cost of infrastructure and other public transport systems (Li and Hensher, 2012, Hensher and Puckett, 2007). In another study conducted on public acceptance, it was found that residents within a congestion charge zone were less likely to accept the charge but the revenue allocation for improvement of public transport services and reducing emissions raised their levels of support for the scheme (Rentziou et al., 2011).

### *3.1.3 Support for road user charge according to sociodemographic groups*

Both genders showed similar support for road user charges. Support also increased with higher education levels. Professionals in managerial positions in health, engineering, IT, and academia demonstrated higher levels of support. Higher-income groups were also more supportive (**Figure 4)** which aligns with findings from other studies (Abulibdeh, 2018).

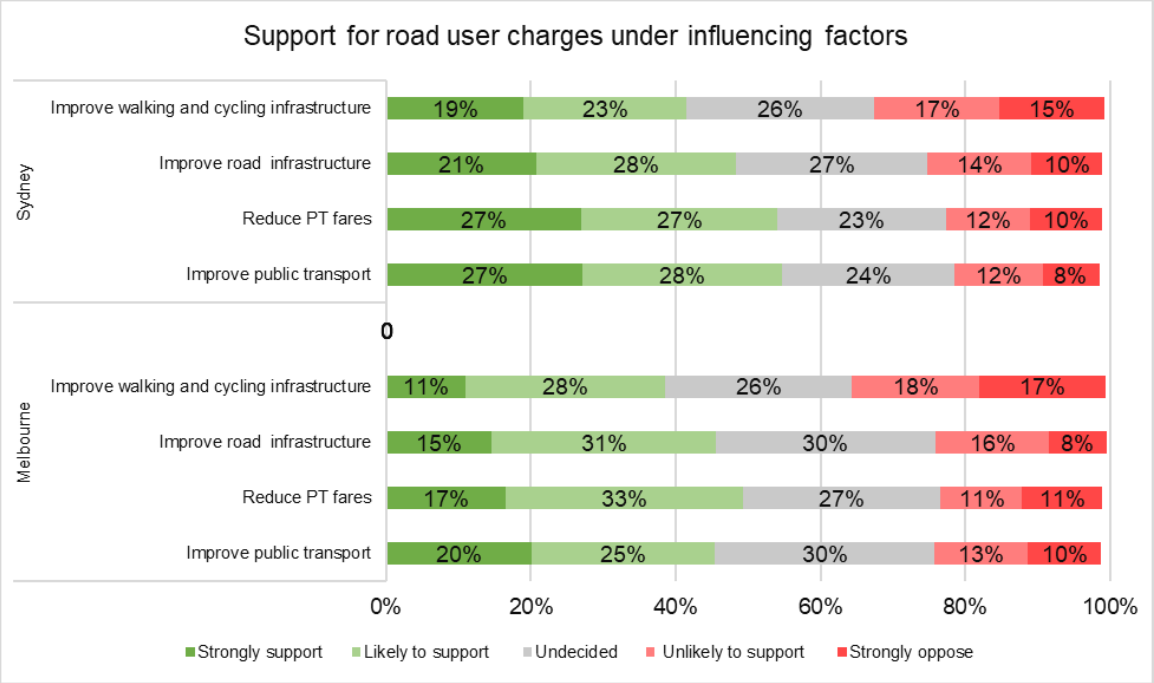


**Figure 3: Support for road user charges under key influencing factors**

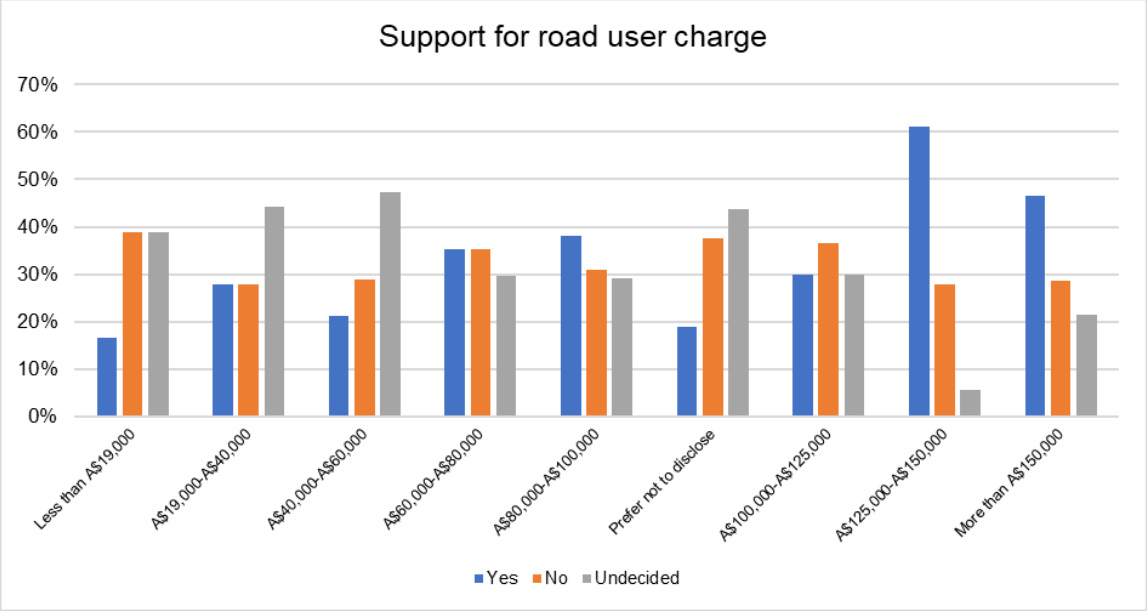


**Figure 4: Support for road user charges according to income levels**

### *3.1.4 Support for road user charges according to preferred mode of transport*

A notable finding from the survey is the significant variation in opinions and acceptance of road pricing among respondents based on their preferred modes of transport (**Figure 5**). A higher percentage of bicycle and public transport users expressed support for road pricing compared to car users, a trend observed in both Melbourne and Sydney. This aligns with existing literature indicating that car users are typically more opposed to road use charges. A substantial proportion of bicycle users and pedestrians were undecided across both cities, which likely reflects the minimal impact of road user charges on cyclists and pedestrians, who would continue to use their existing modes of transport and routes.

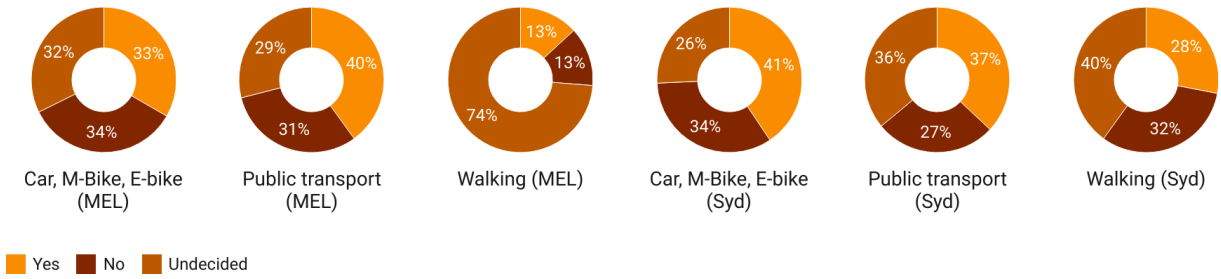


**Figure 5: Support for charges according to preferred mode of transport**

# 4 Logit and artificial neural network choice modelling

Utilising the survey information, this research also developed a robust modelling framework aimed at discerning the factors influencing public acceptance of road pricing and their impact on support levels. The framework follows a three-step process, including (i) identifying key indicators, (ii) constructing Multinomial Logit (MNL) choice models, and (iii) developing Artificial Neural Network (ANN) choice models. The methodology, outlined in **Figure 6**, is chosen to facilitate a comparative analysis of predictions between MNL and ANN models.

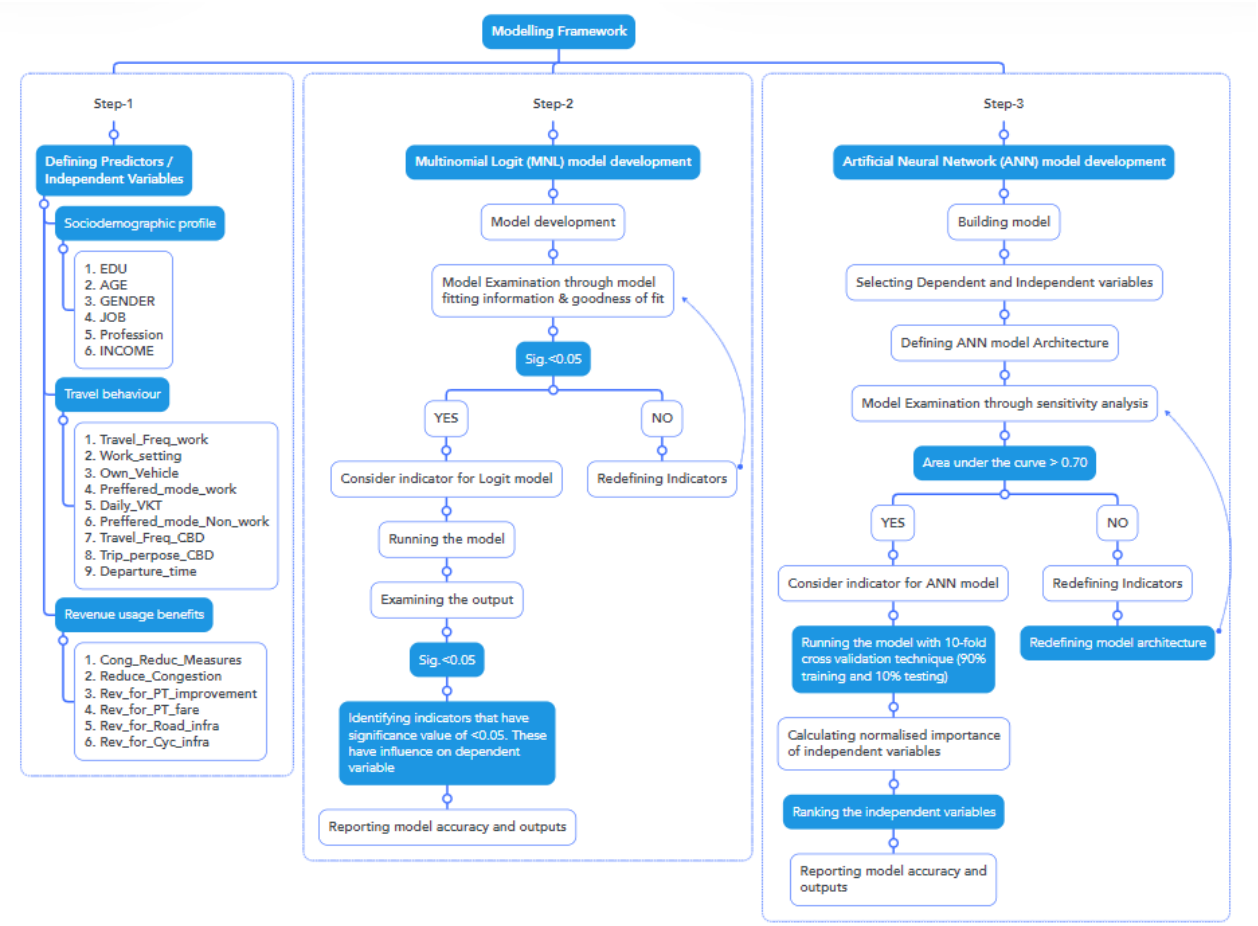


**Figure 6: Choice modelling framework**

## 4.1 Identification of variables

Public support for pricing was considered the dependent variable with three sets of independent variables selected from the survey under the categories “sociodemographic characteristics”, “travel behaviour” and “knowledge/revenue benefits of congestion pricing”.

## 4.2 Multinomial Logit (MNL) model

The dependent variable used for model development is “public support for road user charge” and three set of independent variables were used to develop three different models. After the development of each model, the goodness of fit and model fitting was examined to ensure accuracy and that the model is best fit with the data. The goodness of fit of the model was also assessed, which is a measure of how good the data fits the model (Petrucci, 2009). The best-fit model is then selected to report results and associations between variables.

## 4.3 MNL modelling results

### *4.3.1 MNL travel behaviour index model – Melbourne*

This model analyses how respondents' travel behaviour affects their acceptance of road pricing, considering factors like frequency of travel to work, mode choice for various activities, trip purpose, and visits to the Central Business District. It identifies factors impacting travel behaviour decisions and their influence on road pricing acceptance (shown previously in **Figure 6**). The results in **Table 2** reveal that "Work_setting" and "Trip_purpose_CBD" significantly affect support for road user charges at $p<0.05$, while "Travel_Freq_CBD" impacts support at $p<0.01$. For "Work_setting," respondents whose organisations promote working from home are more supportive of road pricing, with a 15 percent increase in support for each unit increase in the work-from-home setting. Conversely, higher travel frequency to the office reduces support by 20 percent. Results from "Travel_Freq_CBD" indicate that less frequent CBD travellers are more supportive of road pricing, with an 8 percent increase in support for each unit decrease in travel frequency. Conversely, less frequent CBD travellers are more likely to be undecided about road pricing, with a 22 percent increase in the likelihood of being undecided per unit decrease in travel frequency. In terms of trip purposes to the CBD, acceptance of road pricing varies, with business/work and leisure/outing trips showing higher acceptance compared to shopping, school, and medical trips. The likelihood of accepting road pricing decreases by 45 percent with each transition to a different trip purpose.

**Table 2: MNL travel behaviour index model - Melbourne**

| Travel Behaviour Index Model - Melbourne | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| RUC_Support | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | 0.984 | 0.631 | 2.434 | 1 | 0.119 | | | |
| | **Travel_Freq_work** | 0.183 | 0.099 | 3.436 | 1 | 0.064 | 1.201 | 0.99 | 1.457 |
| | **Work_setting*** | -0.172 | 0.073 | 5.585 | 1 | 0.018 | 0.842 | 0.73 | 0.971 |
| | **Preferred_mode_work** | -0.023 | 0.132 | 0.03 | 1 | 0.862 | 0.977 | 0.754 | 1.267 |
| | **Preferred_mode_Non_work** | -0.017 | 0.134 | 0.016 | 1 | 0.901 | 0.983 | 0.757 | 1.278 |
| | **Travel_Freq_CBD** | 0.078 | 0.076 | 1.054 | 1 | 0.305 | 1.081 | 0.932 | 1.253 |
| | **Trip_purpose_CBD*** | -0.613 | 0.241 | 6.473 | 1 | 0.011 | 0.541 | 0.338 | 0.869 |
| Undecided | Intercept | -0.521 | 0.66 | 0.623 | 1 | 0.43 | | | |
| | **Travel_Freq_work** | 0.055 | 0.097 | 0.327 | 1 | 0.567 | 1.057 | 0.874 | 1.278 |
| | **Work_setting** | -0.085 | 0.071 | 1.417 | 1 | 0.234 | 0.919 | 0.8 | 1.056 |
| | **Preferred_mode_work** | 0.148 | 0.117 | 1.582 | 1 | 0.208 | 1.159 | 0.921 | 1.459 |
| | **Preferred_mode_Non_work** | 0.066 | 0.122 | 0.296 | 1 | 0.586 | 1.069 | 0.841 | 1.358 |
| | **Travel_Freq_CBD**** | 0.201 | 0.076 | 6.979 | 1 | 0.008 | 1.223 | 1.053 | 1.419 |
| | **Trip_perpose_CBD** | -0.309 | 0.234 | 1.748 | 1 | 0.186 | 0.734 | 0.464 | 1.161 |
| The reference category is: No. | | | | | | | | | |
| Significance code: <0.001 '***', <0.01 '**', <0.05 '*', | | | | | | | | | |

## 4.4 Artificial Neural Network (ANN) model

The development of Artificial Neural Network (ANN) models involved selecting the same dependent and similar set of independent variables for accuracy assessment in both Melbourne and Sydney. Three distinct ANN models were developed for each city. Among various ANN architectures tested, the Multilayer Perceptron (MLP) shown in **Figure 7** exhibited the highest accuracy in replicating the survey results (Leong et al., 2020). The batch training method was used to train the network. The weights representing the impacts of independent variables on the dependent variable were estimated through a batch gradient descent optimization algorithm. Different activation functions were tested on the data set to develop several models and those with the best accuracy were selected and reported underneath. Hyperbolic tangent, Sigmoid and SoftMax were found to provide maximum modelling accuracy for this data set.

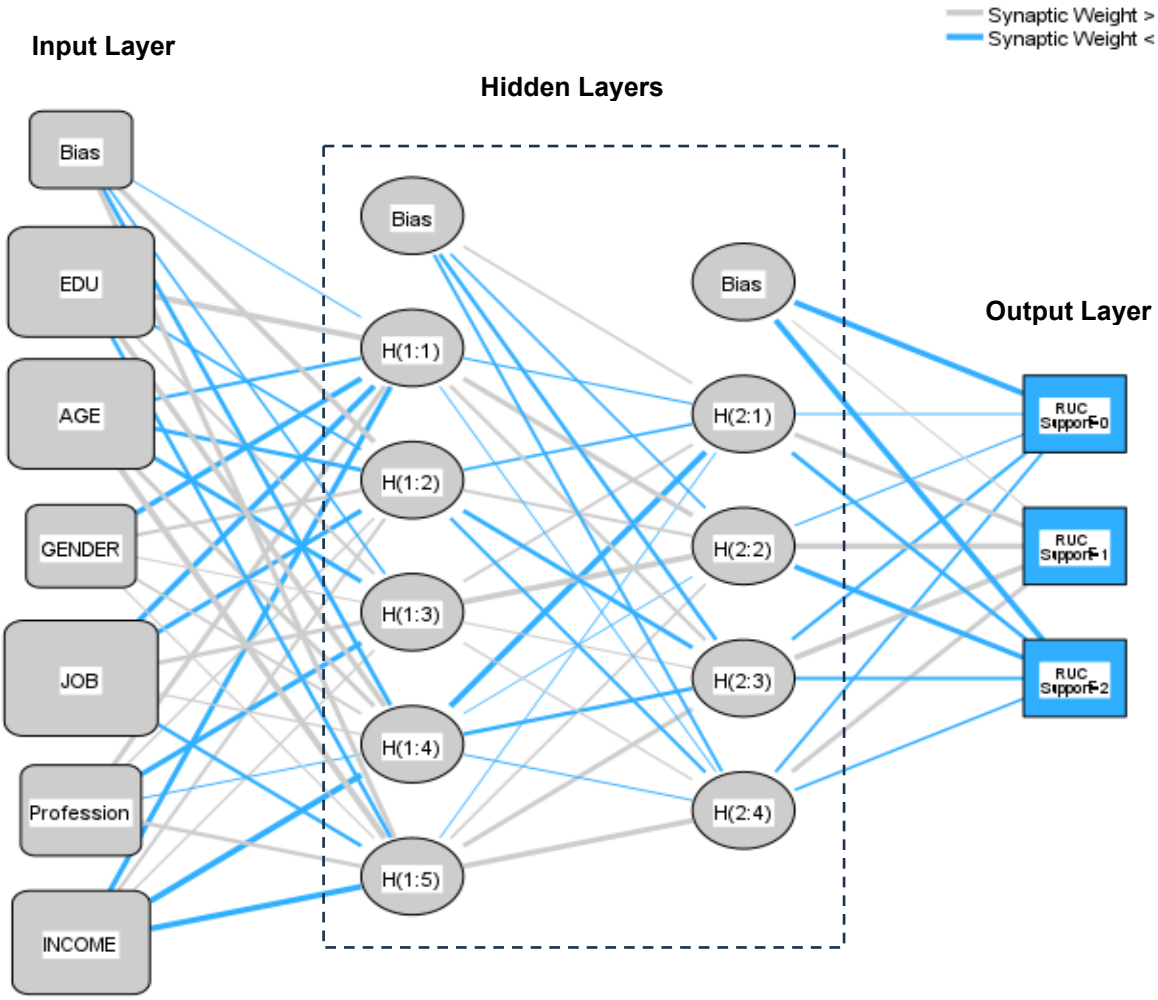


**Figure 7: Artificial neural network model**

## 4.5 ANN modelling results

### *4.5.1 ANN revenue benefits index model - Sydney*

This model achieved an overall accuracy of 87.5 percent, indicating a very good fit with the data. This aligns with the findings of the MNL model for Melbourne and Sydney, as well as the ANN model of Melbourne. The model highlights revenue usage for public transport improvements as the highest important factor (100 percent importance as in **Figure 8)**.

Both Melbourne and Sydney respondents prioritised public transport improvement in the presence of road user charges. Revenue allocation for road infrastructure improvement

followed as the second most important factor, with 82.85 percent importance, indicating Sydney respondents' emphasis on road infrastructure development. Respondents' knowledge about road user charges and their understanding of their benefits in reducing congestion and emissions ranked third in determining acceptance. Lastly, travellers experiencing traffic congestion on their usual routes prioritised congestion reduction measures, underscoring their importance in accepting road user charges.

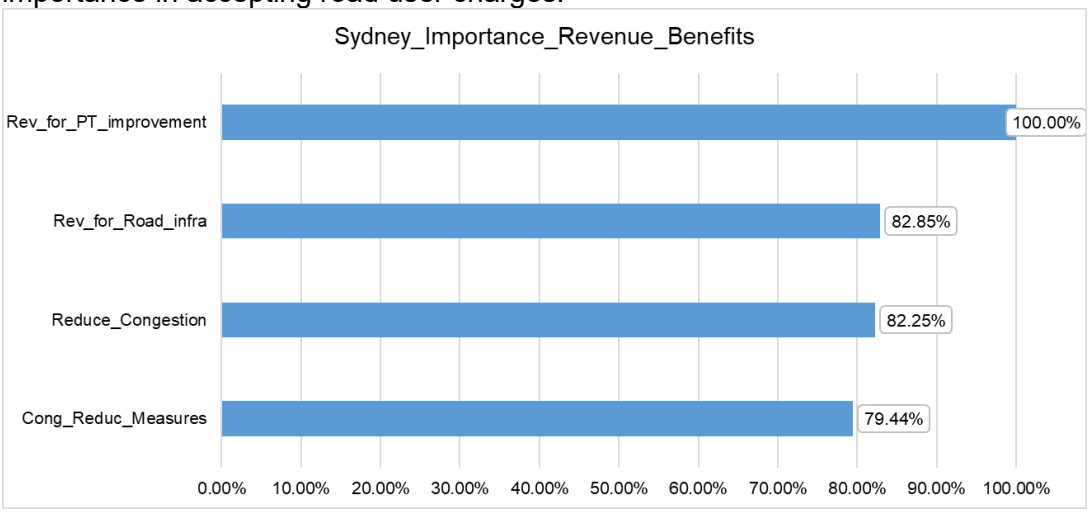


**Figure 8: ANN revenue benefits index model – Sydney**

# 5 Cordon pricing simulation case study

To understand the impacts of road pricing on network performance, this research undertook a traffic simulation case study focused on Melbourne's City and nearby areas, delineated by CityLink, the West Gate Freeway, Punt Road, and Alexandra Parade (**Figure 9).** This area was selected to align with the potential congestion charging zone proposed in the Infrastructure Victoria Strategy 2021–2051 (Infrastructure Victoria, 2020). The research aimed to explore the efficacy of various road network pricing strategies in curbing private vehicle travel, and reducing traffic congestion and emissions. A simulation-based approach was chosen to test diverse scenarios, serving as a foundation for future road pricing deployments in Melbourne. AIMSUN Next 20, a well-established traffic simulation tool was used in the study ((Rahimi et al., 2021, Dia and Panwai, 2010) which adopted a meso-modelling approach that offers a dynamic method for estimating time-dependent itinerary choices in congested networks, considering user perceptions of generalized costs.

**Figure 9: Study area—Melbourne CBD and periphery**

## 5.1 Dynamel–Dynamic Traffic Model for Melbourne

This research is based on an agent-based modelling framework that models car-driver combinations including driver behaviour modelling. It employs various mathematical methods and traffic flow theories, relying on calibrated parameters and detailed transport data to generate comprehensive outputs and traffic statistics. Specifically, the study used the "Dynamel" model, an open access dynamic traffic assignment model for Melbourne (Shafiei

et al., 2018). This mesoscopic model is widely used to analyse traffic dynamics and serves as a reliable decision support system for testing congestion reduction interventions.

## 5.2 Cordon pricing results

The pricing scenarios included a cordon pricing scheme which is a fixed charge that is implemented on vehicles that enter the pricing cordon. Different pricing scenarios were evaluated by setting different cordon charges which were informed by the survey findings. The model was also extended to provide drivers with options to avoid the priced area and make diversions to bypass the cordon zone. The simulation outcomes generated by AIMSUN, which reflected the changes in traffic performance as a result of implementing cordon pricing, were evaluated compared to the baseline no-pricing scenario. The outputs included traffic volumes, travel time, queue length, emissions levels, and travel speeds.

### *5.2.1 Traffic Volumes*

In this study, the simulation runs commenced at 6:00 a.m. with pricing implemented from 8:00 a.m. The scenarios varied the pricing between A$1-A$20 per entry into the priced zone. Changes in traffic volumes become noticeable after the start of the pricing (**Figure 10)**, showing improvements in traffic volumes and indicating that the pricing had an impact on reducing traffic within the cordon area. The traffic has been diverted to other alternative non-priced routes. As evident from the literature that drivers who don't want to pay the charge prefer to take alternative free routes (Lehe, 2019). As expected, higher road user charges would provide further decreases in the number of vehicles entering the cordon. It is interesting to note that potential charges above $10 do not provide any noticeable improvements in traffic. This could be attributed to the fact that in Melbourne, at the time of undertaking the study and behavioural surveys, the public transport daily fare was around $10, which means that if the cordon road user charge exceeds this threshold, then drivers will most likely shift to the lower priced public transport mode to avoid paying excessive charges. This road user fee threshold is important because it signifies an upper limit for the possible charges that drivers are willing to pay.

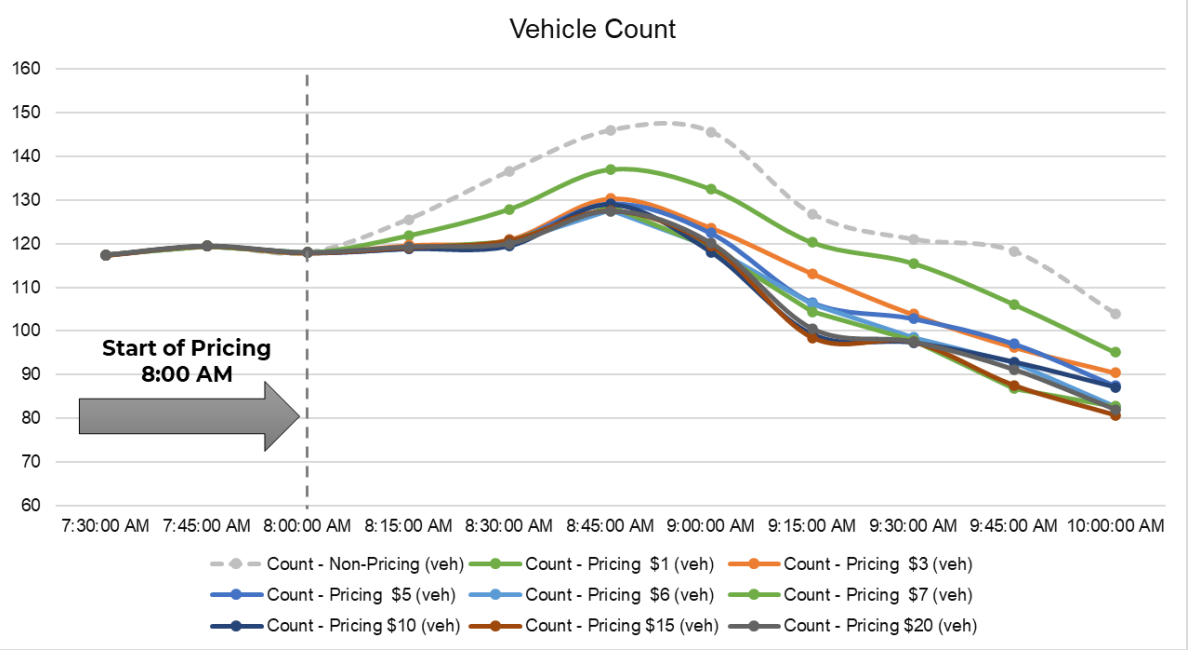


**Figure 10. Simulation results of the cordon pricing zone under different pricing scenarios**

The results showed that the A$1 scenario provides 4% improvement in traffic volumes inside the pricing zone, while the A$3, A$5, and A$10 scenarios showed a 5%, 7%, and 10%

improvement, respectively. The traffic volume improvement then stays constant at around 10% for all other scenarios in which the charging fees are increased up to $20.

### *5.2.2 Emissions*

The emissions model used in AIMSUN takes into consideration vehicle speed, acceleration, and deceleration to estimate emissions and air pollutants which is consistent with established emissions estimation methodologies (Smit et al., 2019). The results revealed that after the start of the pricing period, there was a notable reduction in emissions in the network. The emissions reductions followed the same pattern that was seen in other performance indicators. **Figure 11** compares the carbon emissions within the network in pricing and non-pricing scenarios. It can be seen that in the pricing scenarios, there are fewer red-colour links (road with higher emissions). In the pricing scenario, most links are green except for a few yellow-coloured links, which are indicative of lower emissions overall. The levels of emissions also depend on the total number of vehicles inside the network, where the emissions would be lower if the network is not congested. The maximum reduction was around 10% under a $20 cordon charge scenario. A similar study conducted in London using AIMSUN found a reduction in nitrogen and carbon emissions with the implementation of pricing, which resulted in a 22 percent reduction in emissions using a cordon pricing scheme (Triantafyllos et al., 2019).

**Figure 11. Comparison of emissions within the pricing zone under (right) pricing and (left) non-pricing scenarios.**

## 5.3 Public Transport Scenario

To improve model accuracy, enhancements were made to include public transport ridership and multiclass users reflecting varying values of time. Twelve scenarios were modelled, considering different percentages of public transport ridership (**Figure 12**).

The results showed that shifting 12 percent of drivers to public transport (reflecting policies that aim to accelerate mode shift) could enhance network performance by up to 40 percent, while a 50 percent mode shift scenario (reflecting policies that aim to promote aggressive mode shifts) could improve road network performance by around 70 percent. Other scenarios assumed a shift of 20 percent or 30 percent to public transport, aligned with findings from recent travel behaviour surveys in Melbourne and Sydney. The results showed network performance improvements up to 45 percent and 55 percent, respectively, compared to the baseline scenario. The 30 percent mode shift scenario notably led to a 33 percent reduction in traffic volumes, a 32 percent decrease in total distance travelled, a 55 percent reduction in travel time, a 39 percent reduction in emissions, and a 4 percent increase in travel speeds.

# 6 Discussion

The review of existing literature has highlighted the complexities surrounding road network pricing. The literature indicates a growing discourse on reforming transport taxation to adequately support urban mobility infrastructure. Current funding models, relying on vehicle registrations, fuel excise, and license fees, are seen insufficient and inequitable for future needs, especially with the transition to electric and fuel-efficient vehicles. The literature suggests that road pricing should be integrated into broader taxation reforms, incentivising sustainable transportation choices and alleviating congestion. Revenue from these schemes would fund initiatives to enhance public transport, maintain roads, and improve travel options. The imperative of implementing road pricing as a solution to reduce emissions, particularly in congested urban areas, is expected to gain further prominence.

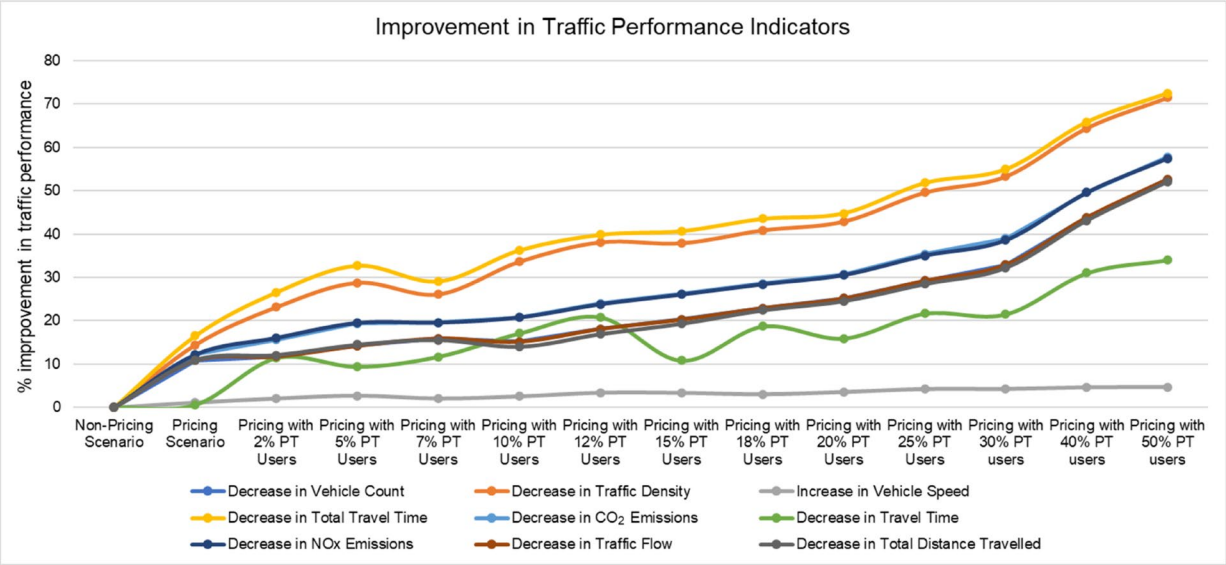


**Figure 12: Improvements in network performance relative to the percent of drivers who will shift to public transport to avoid paying the congestion charge**

The simulation results showed that various pricing strategies have different effects on traffic performance. It would be possible to achieve a reduction of 11 percent in traffic volume, a 20 percent reduction in travel time, a 13 percent reduction in emissions, and a 3 percent increase in travel speeds within the proposed pricing zone under the high-cost pricing scenario. In the high-cost pricing scenario, notable reductions in traffic volumes, travel time, emissions, and an increase in travel speed within the proposed pricing zone were achievable. Furthermore, shifting 12 percent of drivers to public transport could enhance network performance by up to 40 percent. Even more significant enhancements were observed in hypothetical scenarios reflecting more aggressive policy settings resulting in larger proportions of drivers switching to public transport. Scenarios assuming shifts of 20 percent and 30 percent to public transport also showed substantial improvements in network performance, with potential increases of 45 percent and 55 percent, respectively. The results from the Multinomial Logit (MNL) and Artificial Neural Network (ANN) models offered valuable insights. Sociodemographic factors such as gender, education level, employment status, and income levels significantly influenced public support for road pricing in both Melbourne and Sydney. Travel behaviour indicators like frequency, purpose, and mode of travel also consistently affected public acceptance of road pricing in both cities. Perceptions about road pricing and revenue allocation for public transport improvements received comparable support in both cities.

# 7 Conclusions and future research directions

This research has addressed gaps in knowledge and practice, providing decision-makers and stakeholders with valuable insights to facilitate successful implementations of road pricing schemes. By utilising advanced traffic simulation and modelling techniques, combined with

field surveys of public opinion and road-user acceptance, the study has established a reliable platform to evaluate the impacts of road pricing models on congestion, emissions, travel time, and delay reductions. Various road pricing scenarios, including cordon-based schemes, were assessed for their effectiveness in promoting sustainable low-carbon mobility solutions. Unique road pricing choice models were developed based on behavioural surveys in the context of Australian conditions for Melbourne and Sydney. Both conventional Logit models and AI-based deep learning neural network models were employed to identify factors influencing road pricing acceptance, mode choice behaviour, and willingness-to-pay. The research underscores several critical aspects (equity, acceptability) of road network pricing, emphasizing its role in managing travel demand, incentivising sustainable transport choices, and facilitating broader taxation reform. The findings highlight the importance of revenue allocation in influencing public acceptance, particularly when directed towards enhancing public transport and travel options. Pricing frameworks should balance flexibility and ease of use, while considering external costs associated with road travel and environmental impacts. Vertical equity considerations are crucial, necessitating pricing structures that accommodate diverse socioeconomic backgrounds. Dynamic pricing strategies, informed by public input and feedback, would also encourage mode-shift and congestion alleviation.

Looking ahead, future research directions could explore the road pricing scenarios in the presence of different adoption rates of emerging vehicle technologies such as electric vehicles, as well as the increase in parcel delivery vehicles within dense urban area . Surveys should provide respondents with detailed scenarios of road pricing policies to better capture their preferences. Additionally, efforts to improve prediction performance could involve collecting larger samples of responses and exploring new deep learning architectures.

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