Centre for Accident Research
& Road Safety - Queensland (CARRS-Q)

Project No: 6-005

URBAN FREIGHT SHIFTS

Report: Urban Freight Shift (UFS) Forecasting Tool and Transition Scenario Analysis of Urban Freight and Commercial Service Vehicle Trends

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TECHNICAL REPORT DOCUMENTATION PAGE

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URBAN FREIGHT SHIFTS

Report: UFS Forecasting Tool and Transition Scenario Analysis of Urban Freight and Commercial Service Vehicle Trends

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Ethics Statement

Ethical clearance for stakeholder consultations was obtained from the Queensland University of Technology (QUT) (Approval Number: 5537).

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EXECUTIVE SUMMARY

Strong growth in both urban and inter-urban non-bulk freight has been a major contributor to increased freight volumes in Australia over the last four decades. New investments may be needed to respond to changes in urban freight, as well as non-freight commercial vehicle movements. Therefore, the focus of this Urban Freight Shifts (UFS) project is to analyse the current market trends in urban freight and commercial services with a specific focus on the vehicles used in these services (*i.e.,* vehicle type, drive type, mass). Specifically, the overarching **aim of the project is to develop a data-driven and evidence-based forecasting tool to inform future city planning, regulation and infrastructure requirements associated with the current and emerging urban freight (UF) and commercial service (CS) vehicle trends.** The Report 1 presented the initial results from market analysis of current urban freight and commercial service vehicle trends through stakeholder consultations and quantitative analyses of UF and CS vehicle trends. Building on the findings from these initial market trend analyses, the current report presents the integrated UFS forecasting tool while also presents the results from transition scenario analyses.

UFS Forecasting Tool

The UFS forecasting tool was developed to predict the UF and CS vehicles trends from 2022 to 2041 by using the outcomes from the regression models of the historical UF and CS vehicles trends. The tool was developed as an “Excel Workbook” for the study area and was delivered along with this report. The integrated UFS forecasting tool allows for forecasting for the following four dimensions of the UF and CS vehicle trends from 2022 to 2041:

- Number of UF and CS vehicles across postal areas.
- Number of UF and CS vehicles by vehicle class across postal areas.
- Number of UF and CS vehicles by fuel type across postal areas.
- Number of UF and CS vehicles by vehicle mass across postal areas.

Transition Scenario Analysis

Scenario analyses were done to explore what possible/plausible future of UF, and CS vehicle scenarios could look like and to shed light on the sensitivity in forecasting due to the changes in different exogenous variables. This report presents four transition scenarios which explored critical uncertainties in the patterns of future UF and CS vehicle fleet mix. The four scenarios were labelled as:

1. Urban densification,
2. Slowing economic growth,
3. Decarbonisation policy push, and
4. User pays road funding.

The results from transition scenario analyses showed the greater influence of urban densification and economic growth on freight and commercial service activities. A higher level of urban densification and economic activities were found to increase the demand for higher number of UF and CS vehicle registrations over the time.

The scenario analyses signified the importance of implementing Electric Vehicle (EV) related policy measures to support the acceleration of alternate fuel driven vehicle uptake in the Australian freight and commercial service sectors. Moreover, the EV supply was found to play a crucial role in the freight and commercial service vehicle fleet electrifications. On the other hand, restrictions on internal combustion engine (ICE) vehicle registrations were also found to contribute significantly to aid the transport electrification goal.

The scenario analyses results showed that a higher level of commercial activities is likely to contribute towards a higher percentage of light commercial vehicle registration for delivering small payloads in urban areas. Hence, the share of heavy vehicles in such scenarios were found to be lower. These results demonstrated the interplay of supply-chain mechanism in the freight and commercial service vehicle fleet mix ambition. For example, with an increased adoption of a “spoke and hub” approach of supply-chain mechanism, larger vehicles can serve the hubs while the smaller vehicles can serve the spokes. As such, in future, such supply-chain mechanism may contribute towards decreased heavy vehicle flow in the urban areas.

Conclusions

The report presents:

- The integrated UFS forecasting tool; and
- Results from transition scenario analyses of UF and CS vehicle trends.

The outcomes of the UFS project will provide planners and decision makers with a basis for a data-driven and evidence-based platform to create future scenarios on UF and CS vehicle fleet mix ambitions.

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Abbreviations and Acronyms

ABS	Australian Bureau of Statistics
ARIA	Accessibility and Remoteness Index of Australia
ASGS	Australian Statistical Geography Standard
BITRE	Bureau of Infrastructure and Transport Research Economics
CBD	Central Business District
CS	Commercial Service
DEM	Digital Elevation Model
DITRDCA	Department of Infrastructure, Transport, Regional Development, Communications and the Arts
EDV	Electric Delivery Vehicle
EV	Electric Vehicle
FS	Fractional Split
GCM	Gross Combination Mass
GTK	Gross tonnes-kilometres
GVM	Gross Vehicle Mass
HVNL	Heavy Vehicle National Law
ICE	Internal Combustion Engine
LCV	Light Commercial Vehicle
LEV	Light Electric Vehicle
LPG	Liquified Petroleum Gas
LR	Linear Regression
MNLFS	Multinomial Fractional Split
MVC	Motor Vehicle Census
NB	Negative Binomial
NFDH	National Freight Data Hub
NHVR	National Heavy Vehicle Regulator
NTC	National Transport Commission
OCM	Open Charge Map
OLFS	Ordered Logit Fractional Split
PBS	Performance Based Standards
QUT	Queensland University of Technology
RUC	Road user charge
SA	Statistical Area
SMVU	Survey of Motor Vehicle Use
SRTM	Shuttle Radar Topography Mission
t	tonnes
TMR	Department of Transport and Main Roads
UF	Urban Freight
UFS	Urban Freight Shifts
VKT	Vehicle kilometres travelled

Chapter 1: INTRODUCTION

1.1 BACKGROUND STATEMENT

A major contributor to increased freight volumes in Australia over the last four decades has been strong growth in both urban and inter-urban non-bulk freight (4.8 and 4.4 per cent per annum respectively), which is primarily carried by road transport (BITRE, 2019). The Bureau of Infrastructure and Transport Research Economics (BITRE) has forecasted urban road freight to grow by nearly 60% over the 20 years to 2040 (BITRE, 2019). It is essential to better understand what the future needs of urban freight providers will be in order to service this growth in freight volumes. These needs will vary with factors such as vehicle size, mode, and other relevant technological requirements.

The need for this better planning aligns with the National Urban Freight Planning Principles, which the Infrastructure and Transport Ministers endorsed in May 2021 (DITRDC, 2021). These principles bring together transport and land use planning and are intended to flow through to strategic planning and detailed planning guidance documents over time. One of the seven principles is to respond to changes in freight movements, including smaller scale freight movement and emerging technologies.

Responding to changes in urban freight, as well as non-freight commercial vehicle movements may call for new investments. For instance, there may be an increased need for electric and hydrogen vehicle charging/refuelling infrastructure (partly driven by the increasing demand for reduced emissions). As freight in the future may also be carried by connected and automated vehicles (which will most likely offer electric, and potentially hydrogen fuel options), investments in relevant supporting digital and physical infrastructure will also need to be considered. Responding to changes may also call for existing regulation, pricing, and maintenance arrangements to be re-examined. For example, impacts from the emerging trend towards smaller trucks providing urban freight (UF) and commercial services (CS) could be reflected in maintenance decisions.

An increasing amount of data is becoming available to track and analyse urban freight movements. Some of this is already occurring through the development of the National Freight Data Hub and with Freight Data Exchange pilots. There is scope for this new data to be complemented by information about factors influencing emerging urban freight and commercial service trends, to inform an understanding of what future scenarios may develop. The scope of the Urban Freight Shifts (UFS) project is to provide an evidence-based and data-driven integrated forecasting tool to inform what future urban freight and commercial vehicle scenarios could look like. The outcome of this project will provide planners and decision makers with a basis for an evidence-based platform to create future scenarios.

1.2 PROJECT AIMS AND OBJECTIVES

The overarching aim of the UFS project is to develop a data-driven and evidence-based forecasting tool to inform future city planning, regulation and infrastructure requirements associated with the current and emerging urban freight (UF) and commercial service (CS) vehicle trends.

Specifically, the project develops a systematic analytical framework of the relevant vehicle classes, fuel types and vehicle masses while also examining the underlying demand mechanisms to understand recent and emerging UF and CS vehicle trends. The systematic analytical framework is developed as an integrated forecasting tool.

The forecasting tool is developed by integrating outcomes from regression (predictive) models of UF and CS vehicle trends. The outcomes of the regression models were presented in Report 1. Regression models were developed to identify how different explanatory variables are related to the numbers of vehicles in each postal area of the study area to inform predictions of future vehicle numbers. The models focused on:

- The total number of UF and CS vehicles
- The proportions of each vehicle type of UF and CS vehicle
- The proportions of UF and CS vehicles by fuel type
- The proportions of UF and CS vehicles by mass

The integrated forecasting tool is developed to predict future UF and CS vehicle trends (vehicle count, vehicle class, fuel types and vehicle mass) for the years 2022 through 2041. Moreover, to inform the policy decisions of UF and CS vehicle fleet mix ambition, scenario analyses are done by developing a series of narratives and portraying those through the regression models of the integrated forecasting tool.

1.2.1 Structure of the Report

Report 2 has the following structure:

Chapter 2: Presents the UFS forecasting tool.

Chapter 3: Presents the findings from the transition scenario analyses.

Chapter 4: This chapter presents the conclusions from Report 2.

Chapter 2: UFS FORECASTING TOOL

An integrated forecasting tool were developed to predict the UF and CS vehicle trends (number of vehicles, number of vehicles by vehicle class, number of vehicles by fuel type and number of vehicles by vehicle mass). The tool was developed to predict the UF and CS vehicle trends for the years 2022 to 2041.

2.1 METHOD

The integrated UFS forecasting tool (referred to as UFS tool hereafter) was developed by using the outcomes from the regression models of the historical UF and CS vehicles trends[1]. Regression models were developed to identify how different explanatory variables are related to the numbers of vehicles in each postal codes within the study area[2] to inform predictions of future vehicle numbers. The models focused on:

- The total number of Urban Freight (UF) and Commercial Service (CS) vehicles
- The proportions of each vehicle type of UF and CS vehicle
- The proportions of UF and CS vehicles by fuel type
- The proportions of UF and CS vehicles by mass

The explanatory variables considered in developing these regression models were chosen based on the findings of the stakeholder consultations, evidence from earlier studies and represented land use, built environment, socio-economic factors and transport infrastructure. For the regression analysis, the estimates of current and past vehicle registration data available in the Australian Bureau of Statistics (ABS) Motor Vehicle Census (MVC) 2017 to 2021 were used. The list of these variables and the outcomes of the regression models were presented in Report 1.

The UFS tool was developed to predict the UF and CS vehicles trends from 2022 to 2041. The conceptual framework of developing the integrated UFS forecasting tool is presented in Figure 2.1. The tool was developed as an "Excel Workbook" and was delivered along with this report. The predictive equations used in developing the tool are presented in Appendix A. All the relevant assumptions and calculations were integrated and coded in the excel workbook. The integrated tool allows for forecasting for the following four dimensions of the UF and CS vehicle trends from 2022 to 2041 –

- Number of vehicles across postal areas.
- Number of vehicles by vehicle class across postal areas.
- Number of vehicles by fuel type across postal areas.
- Number of vehicles by vehicle mass across postal areas.

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[1] The analytical framework used for developing the regression models are presented in Appendix A.

[2] Across Australia, there are 2,310 postal areas, 1,030 of which are in urban areas from Australian Capital Territory (ACT), New South Wales (NSW), Victoria (VIC), Queensland (QLD), South Australia (SA) and Western Australia (WA) were considered as study area for this project (as described in Report 1).

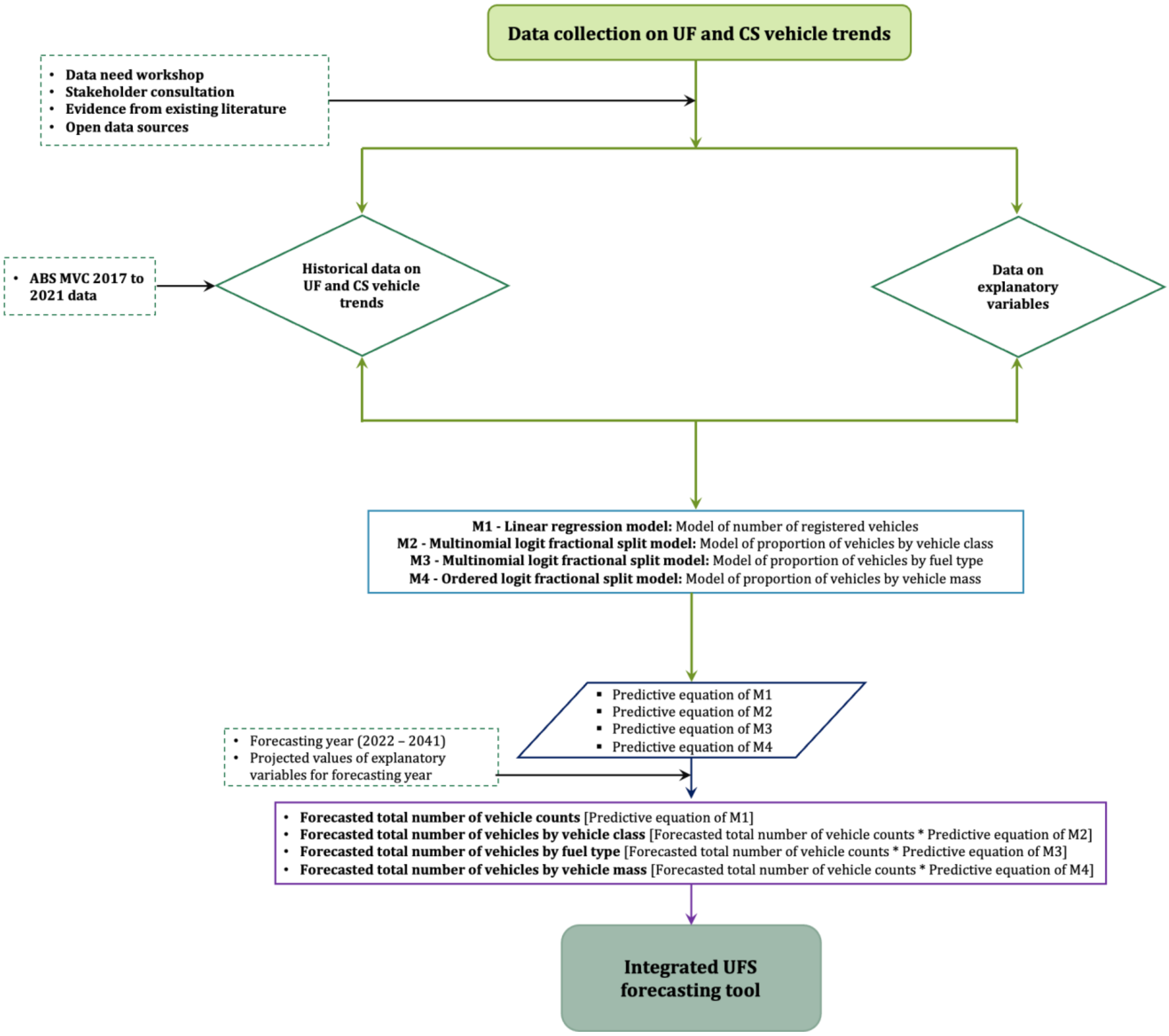


Figure 2.1. Conceptual Framework of the integrated UFS forecasting tool

The UFS tool was developed by considering changes in population growth over 2022 to 2041, while all other exogenous variables were considered to remain the same – **thus, the forecasting tool forms the 'base case' scenario for any further scenario analysis**[3]. Figure 2.2 presents the historical and forecasted number of UF and CS vehicles – base case scenario prediction values. From Figure 2.2, it can be observed that the forecasted vehicle numbers across the urban area are likely to increase with increase in population over time (while everything else remain the same as 2021). This is consistent with the historical UF and CS vehicle trends indicating that population growth is likely to increase economic activities which in turn is likely to contribute towards higher level of freight and commercial service vehicle registrations in future (if everything else remain the same as in 2021).

[3] All the relevant methodologies of the forecasting tool are presented in the Excel Workbook.

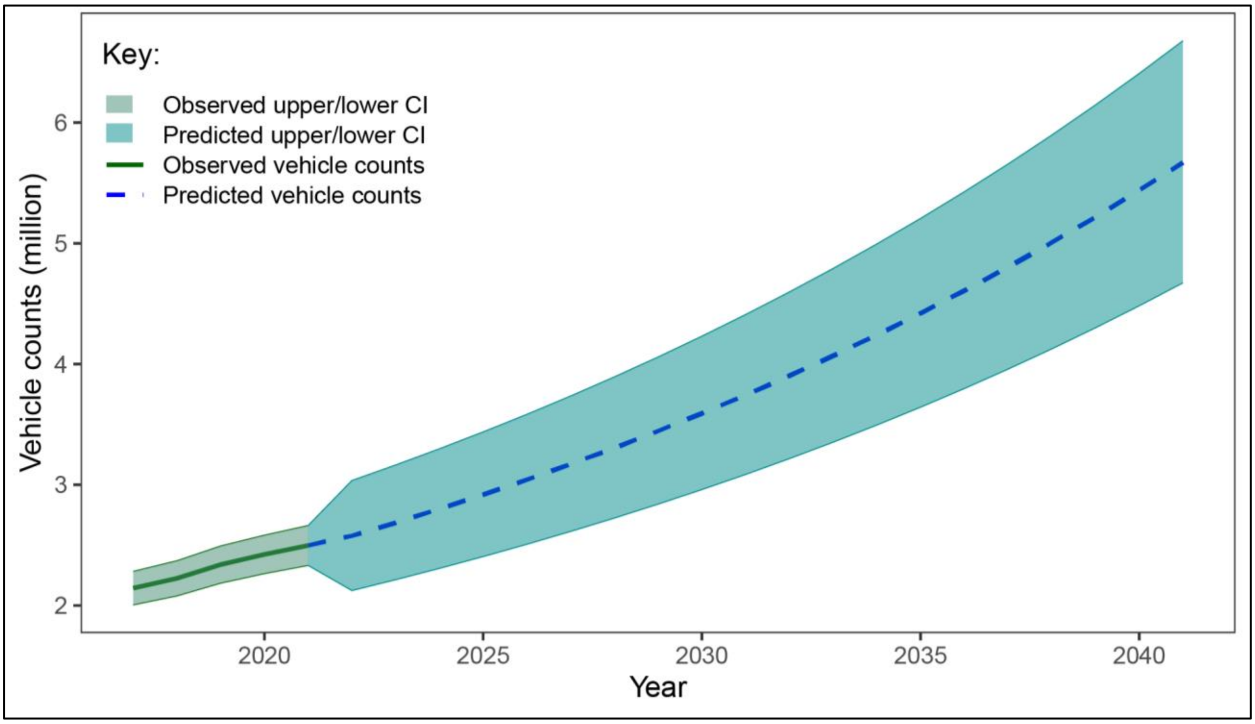


Figure 2.2. Historical and forecasted annual urban freight and commercial service vehicle counts (in millions) in urban areas between 2017 and 2041 [CI = 95% Confidence Interval]

It is worthwhile to mention here that the UFS tool allows for modifying assumptions of different exogenous variables (the relevant equations are in-built in the Excel Workbook). Thus, the tool allows to test for sensitivity of the predicted/forecasted values relevant to any modelling assumptions and/or other relevant data generation assumptions[4]. As such, it is possible for the DITRDCA or any other analyst to revisit the assumptions and predict the values in UF and CS vehicle trends for any possible/plausible changes in the relevant exogenous variables.

[4] The assumptions in any exogenous variables can be tested by changing the variables in the 'Basic variables' sheet of the Excel Workbook, which will automatically change any other relevant values across all other sheets and hence the tool is user friendly and simple.

Chapter 3: TRANSITION SCENARIOS

Scenario analyses were done by considering four possible/plausible scenarios to explore what future of urban freight and commercial service vehicle scenarios could look like. The developed scenarios were analyses by using the forecasting tool to predict the effects of the plausible/possible changes on the future UF and CS vehicle trends. This also shed light on the sensitivity in forecasting due to the changes in different exogenous variables. This report presents four scenarios which explored critical uncertainties in the patterns of future UF and CS vehicle fleet mix. The four scenarios were labelled as:

1. Urban densification,
2. Slowing economic growth,
3. Decarbonisation policy push, and
4. User pays road funding.

3.1 METHOD

Transport sector, in general, is likely to be associated with uncertainties in demand and supply due to technological, economical, societal, behavioural and/or political changes. However, the directions and the results of these changes are likely to be unknown in the present time mostly because we do not have the knowledge of the future. Thus, there might be several possible/plausible transport future end states. Scenarios can be developed by considering different end state conditions. Thus, scenario analysis allows us to incorporate uncertainties to inform future policy decision. In fact, scenarios could be stretching (overarching or conflicting) portraying significant divergence from the "business as usual" trajectory. Thus, scenario analysis is becoming an important policy decision tool in the transport sector since it can inform what potential changes might require in achieving a desired policy goal or a desired future transport end state (such as a goal of net zero emissions or a goal of zero road deaths in transport). As such, in this project, scenario development and analysis exercise are adopted to demonstrate what the future UF, and CS vehicle scenarios could look like. Further, it also demonstrates the implications of the integrated UFS forecasting tool for incorporating the effects of uncertainty in UF and CS vehicle fleet mix ambitions.

Scenario analysis is done by developing a series of narratives which are portrayed through several quantitative assumptions of the exogenous variables. The quantitative assumptions in each exogenous variables of the relevant scenario then feed into the predictive models to test the implications of changes in the UF and CS vehicle trends which can inform future policy decision process. It is important to realise that scenarios are not only just predictions, and there might be no right answer in the narrative of a scenario. As such, scenario analysis results presented in this report are rather illustrations of possible/plausible changes that are likely to shape future UF and CS vehicle trends. Considering a wide range of circumstances, scenario analyses were done to inform policy decisions relevant to any future UF and CS vehicle fleet mix ambition.

Scenario analyses were done by following the steps below –

- Development of scenario narratives (qualitative).
- Mapping scenario summaries into exogenous variables considered in the regression models of UF and CS vehicle trends (quantitative parameters).
- Identify levels of exogenous variables to portray the scenario narratives (quantitative assumptions).
- Predictions of the UF and CS vehicle trends for the relevant assumptions in the exogenous variables for each scenario.

The process of generating scenario analysis results is presented in Figure 3.1.

3.1.1. Scenario Narratives

The critical uncertainty that may arise in the freight and commercial service sectors could be attributed to changes in urban residential densification, land use, e-commerce, online delivery, electric vehicle supply, economic growth and/or decarbonisation policy. Uncertainties in these attributes were highlighted as the possible changes in urban freight future during the stakeholder consultation (as presented in Report 1). Therefore, a wide range of changes in the circumstances relevant to these attributes were considered in developing the scenario narratives.

The scenario narratives were developed and finalised in collaboration with the DITRDCA. However, it is worthwhile to mention here that a wide range of alternative scenarios narratives could be developed and analysed. Below are the narrative summaries of the scenarios:

Scenario 1: Urban densification

This scenario envisages a greater trend towards densification in our major cities such as Sydney, Melbourne and Brisbane. Residential development will be focussed particularly on public transport corridors to ensure residents have easy access to buses, trains and metro services. Urbanisation could see greater residential development, but on average smaller residences which have a greater reliance and use of public transport and ridesharing services together with lower rates of private car ownership – resulting in less need for private carparking. E-Commerce and online delivery services would be dominant, with households making smaller but more frequent transactions. These last mile deliveries would be made increasingly by low and zero emissions methods of transport such as e-bikes, e-scooters and electric vans, trucks and drones (which are well suited to the task of delivering over short distances and recharging at depots) to preserve resident amenity in these densely populated areas. An increase in electrified transport would demand a greater investment in the EV fast charging stations and associated infrastructure.

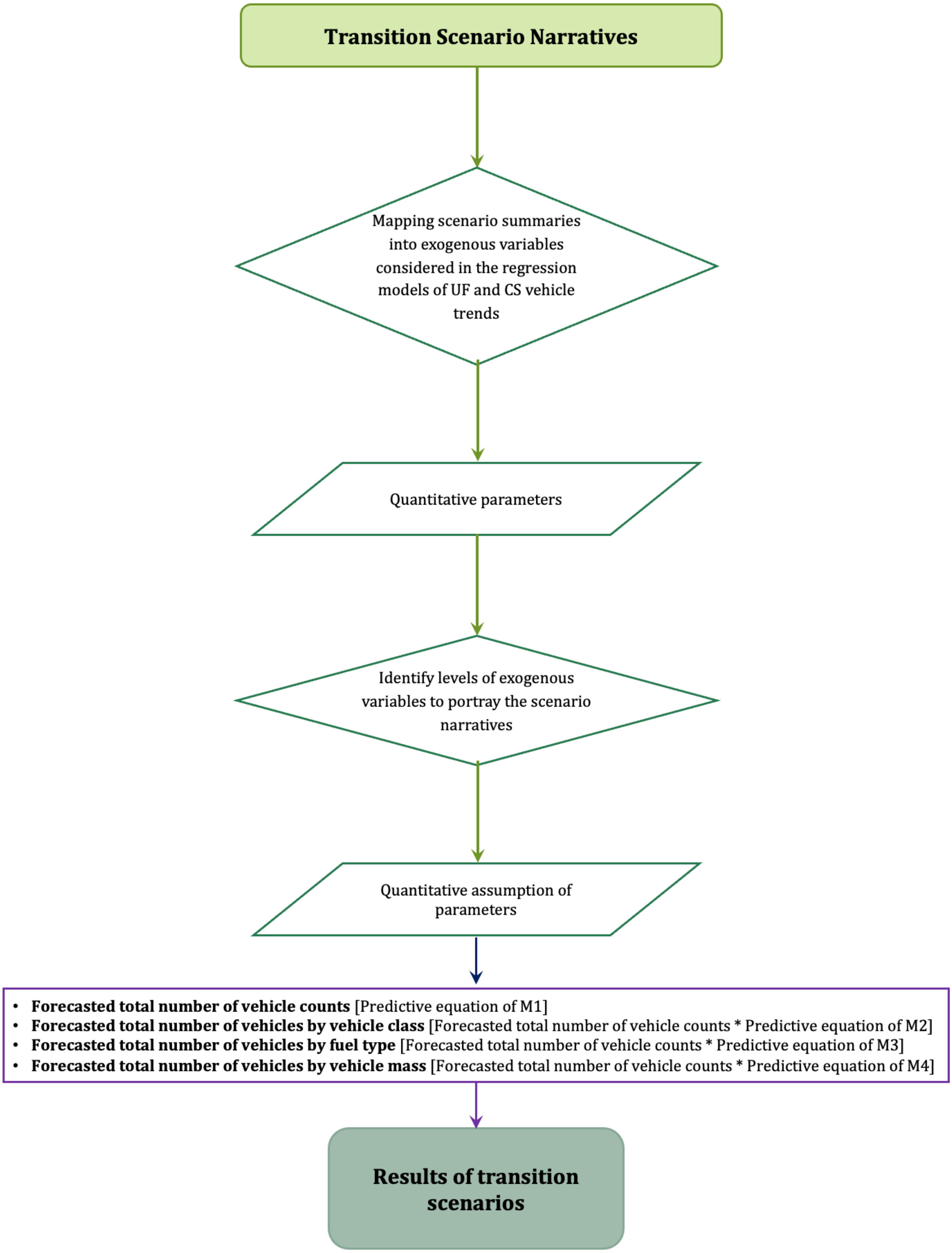


Figure 3.1. Process of generating scenario analysis results *[M1 - Linear regression model: Model of number of registered vehicles; M2 - Multinomial logit fractional split model: Model of proportion of vehicles by vehicle class; M3 - Multinomial logit fractional split model: Model of proportion of vehicles by fuel type; M4 - Ordered logit fractional split model: Model of proportion of vehicles by vehicle mass]*

Scenario 2: Slowing economic growth

This scenario describes below-trend economic growth through to 2041 (the timeframe examined by the UFS tool). Below-trend growth could be attributed to an external macroeconomic shock (such as seen with COVID-19 in 2020), budgetary pressures resulting in subsequent austerity measures, a decline in immigration, rising energy costs (and/or energy insecurity crises) related to climate commitments and other demographical changes such as an ageing population with a shrinking workforce. Slow (or no) economic growth and budgetary pressures would restrict governments' ability to invest in and support transport infrastructure. Road networks may increasingly deteriorate and addressing supply chain stress points would be less of a budget priority. Cities may become much more congested with traffic, constraining the efficiency of urban freight. This scenario could encourage governments to look at ways to increase economic growth and boost the workforce by promoting immigration levels or stimulating the economy in other ways. State local governments could be enticed to further engage in urbanisation and densification to rein in or limit infrastructure costs associated with greenfield residential developments.

Scenario 3: Decarbonisation policy push

This scenario is about an increased political ambition by governments at all levels to meet Net Zero commitments and decarbonise all sectors as quickly as possible. Under this scenario, there would be a push towards electrification of transport, with incentives and support for electric vehicles of all types. At a state, territory or local level policies around 'low emissions' zones could be established in CBD areas which specifically exclude travel by internal combustion engine vehicles. Sales of such new vehicles may be prohibited in future. In the short to medium term, moves to decarbonise the economy could involve instability and volatility in the energy grid as traditional baseload power is phased out while the grid is put under pressure with increased demand on renewables. Energy regulators such as the Australian Energy Market Operator potentially more frequently playing an interventionist role in the market as seen during the 2022 energy crises until such time as there is a more optimal balance between the supply of baseload power, sufficient energy storage such as through battery storage and appropriate demand management controls (such as discouraging use of EV chargers in peak times through education, price signals or regulatory mechanisms). This could provide a significant bump to GDP and GSP as households, residences and government accelerate their transition from traditional sources of energy to renewables – with investments made in EVs, residential and commercial battery storage, solar PV systems, efficient and smart appliances, residential and commercial EV charging stations whilst the government could initially see a gradual but accelerating reduction in fuel excise revenue. Autonomous electric vehicles will become more common as the technology develops. This may facilitate cheaper and more efficient delivery of freight 24-7, particularly over the last mile. It may lead to many fewer trips by customers to stores, replaced by many trips from distribution centres to homes and offices.

Scenario 4: User pays road funding

'User pays road funding' describes circumstances in which a distance-based road user charging regime is implemented for all vehicles on all roads. This could coincide with a greater use of connected and autonomous vehicles, coupled with declining private car ownership. Distance-based charges would be imposed on all vehicles regardless of method of propulsion (i.e. whether it uses petroleum fuel or not). This trend would impact government fees, taxes and revenues at all levels if the population at large opts against gaining a drivers licence and/or purchasing a vehicle for private use. To replace the lost revenue streams associated with stamp duty, licencing, luxury car tax and fuel excise revenue, cost recovery distance-based charges would be levied on those businesses providing transport as a service. Those charges would be passed on to customers as part of the cost of the transport service. Cost recovery would ensure governments have sufficient funding to build and maintain the road network, assuming that revenue is hypothecated.

3.1.2. Mapping Scenarios to Quantified Parameters

The developed scenario narratives are mapped to different exogenous variables that were considered in regression models. It is worthwhile to mention here that the scenario narratives might not directly relate to or translate to the available exogenous variables in the regression models. However, the available exogenous variables might serve as surrogate measures to collectively represent the effects of the considered wide range changes in the scenario narratives. It is possible to revisit these assumptions in the integrated UFS forecasting tool, which provides the DITRDCA with significant flexibility to test for other possible/plausible future transition scenarios. Table 3.1 presents the mapped exogenous variables to each scenario while also indicating the assumed illustrative levels of changes in those exogenous variables relevant to those scenarios. The possible explanations of the relationships between the identified exogenous variables and UF and CS vehicle trends could be -

- Medium-high, and high income population: Volumes of freight are likely to be influenced by economic factors, with volumes increasing when the economy is strong and the proportion of population with higher income level increases.
- Gross State Product (GSP): Demand for freight is a product of demand and supply of goods and services. Thus, economic growth is likely to increase freight and commercial service activities.
- Residential area density: Volumes of freight were largely influenced by economic factors, with volumes increasing when the economy was strong and as a result, population are more likely to migrate from rural to urban areas.
- Commercial area density: Growth in small payload, urban delivery, particularly of hot foods and groceries to customers' homes are likely to contribute towards increase in commercial area density.
- Key freight route (rail and road): Higher freight activities warrant higher investments in key freight infrastructures.
- EV supply: Higher level of EV supply is likely to encourage more electric vehicle adoption in the freight and commercial service sector.
- EV fast charging stations: Urban area densification and/or e-commerce activities may contribute towards higher level of freight activities and to encourage more EV adoption for freight activities in those areas, a higher level of investments in EV infrastructures might be required.
- EV subsidy: EV subsidies can encourage higher adoption of electrification of the freight and commercial service vehicles.
- Restrictions of internal combustion engine (ICE) vehicle sale: The push to net zero through the restrictions on ICE vehicle sale can be achieved.

3.1.3. Quantified Assumptions of the Parameters

A wide range of values for the mapped exogenous variables were identified to cover an extensive measure of uncertainties across different scenarios. The values of exogenous variables were assumed by considering several extremities (provocative) in order to draw out some of the relevant changes that might be required to achieve an expected transport policy goal in the UF and CS vehicle fleet mix. As such, some of the assumed values of exogenous variables may represent some infeasible/expected/possible/plausible reality of 2041 (the timeframe considered in the UFS forecasting tool). As mentioned before, the integrated UFS forecasting tool allows to test for any relevant assumptions of the exogenous variables and hence, can be easily tested for any other assumed values. Table 3.2 presents the assumed quantitative values of the exogenous variables representing different illustrative levels.

Table 3.1. Mapping Scenarios to Quantified Parameters and the Assumed Illustrative levels

SCENARIOS	EXOGENOUS VARIABLES								
	Medium-high and high income population ratio	Gross State Product (GSP)	Residential area density	Commercial area density	Key freight route (Rail and Road)	EV supply	EV fast charging station	EV subsidy	Restrictions on ICE vehicle sale
	Assumed Illustrative Levels								
Urban densification (changes in the major cities only)	H	H	H	H	C	M	H	M	C
Slowing economic growth	L	L	M	L	L	L	L	L	L
Decarbonisation policy push	M	M	C	M	L	H	H	H	H
User pays road funding	C	M	C	H	H	C	M	M	C
Note: H = High; M = Medium; L = Low; C = Current trend (Business as usual)									

Table 3.2. Quantitative Assumptions of the Quantified Parameters

SCENARIOS	EXOGENOUS VARIABLES								
	Medium-high and high income population ratio	Gross State Product (GSP)[5]	Residential area density	Commercial area density	Key freight route (Rail and Road)	EV supply	EV fast charging station	EV subsidy	Restrictions on ICE vehicle sale
Urban densification (changes in the major cities only – Brisbane, Sydney and Melbourne)	25% increase	Sydney = 2.25; Melbourne = 4; Brisbane = 6[6]	20% Industrial area are converted to Residential area	20% industrial area are converted to Commercial area	No change	25% of additional EV uptake is observed in the major cities	Installation of 146 new EV fast charging station per year[7]	14% increase in fuel tax are rewarded towards EV subsidy	No change
Slowing economic growth	15% decrease	ACT = 1.5; NSW = 1; VIC = 2; QLD = 0.5; SA = 1.5; WA = 1.5	17.5% Industrial area are converted to Residential area	2.5% industrial area are converted to Commercial area	5% increase in existing key freight rail and 10% increase in existing key freight road	5% of additional EV uptake is observed	Installation of 62 new EV fast charging station per year	2% increase in fuel tax are rewarded towards EV subsidy	5% of additional EV uptake replaced those existing Diesel and petrol driven vehicles

[5] The historical trends (from 1991 to 2022) in GSP across different jurisdiction were considered in generating the values of GSPs. For a high level of GSPs, a 60% increase in average historical GSPs were assumed. For a medium level of GSPs, a 25% increase in average historical GSPs were assumed. For a low level of GSPs, a 25% decrease in average historical GSPs were assumed.

[6] Brisbane is likely to have a higher increase in economic growth due to the 2032 Olympic and Paralympic game. The highest value of GSP = 5.8 was achieved in QLD in the year of 1998 and hence, to reflect the possible economic growth in Brisbane, a value of GSP = 6 is assumed in Scenario 1.

[7] Number of historical and predicted EV fast charging points and rate of installing were computed following random assignment approach. the predicted values of EV fast charging points are shown in Appendix B.

Decarbonisation policy push	15% decrease	ACT = 4; NSW = 1.75; VIC = 3; QLD = 1; SA = 2.25; WA = 2.25	No change	20% industrial area are converted to Commercial area	5% increase in existing key freight rail and 10% increase in existing key freight road	25% of additional EV uptake is observed	Installation of 146 new EV fast charging station per year	25% increase in fuel tax are rewarded towards EV subsidy	Within 5 km of all Central Business Districts (CBDs), ICE vehicle registrations were banned
User pays road funding	No change	ACT = 4; NSW = 1.75; VIC = 3; QLD = 1; SA = 2.25; WA = 2.25	No change	40% industrial area are converted to Commercial area	15% increase in existing key freight rail and 20% increase in existing key freight road	No change	Installation of 116 new EV fast charging station per year	14% increase in fuel tax are rewarded towards EV subsidy	No change

3.1.4. Results of Transition Scenario Analyses

In the final stage of the transition scenario analysis, the quantitative assumptions in each scenario (as presented in Table 3.2) were fed into the integrated UFS forecasting tool in generating the predicted values of UF and CS vehicle trends for the year 2041 (the timeframe of the UFS forecasting tool). It is worthwhile to mention here that the scenario analysis also involved backcasting in several instances. For example, in imposing the ICE restriction assumption in Scenario 3, the forecasted values in ICE vehicle for the designated postal areas were redistributed to EV/hybrid vehicles. As is evident, scenario analysis is not only predictions, but it also incorporates possible/plausible changes that are likely to shape future UF and CS vehicle fleet mix ambition.

In the following sections, the forecasted UF and CS vehicle trends for the illustrated scenarios are presented along with the base case scenario (presented in Figure 2.2) for the year 2041. Annual vehicle counts across different transition scenarios are presented in Figure 3.2. Figure 3.3 presents the annual vehicle counts by vehicle classes across the transition scenarios. Comparison of annual vehicle counts across different transition scenarios are presented in Figure 3.4. Annual vehicle counts for EV/hybrid/other fuel driven vehicles across different transition scenarios are presented in Table 3.4. Finally, annual vehicle counts for vehicles with >12t mass are presented in Figure 3.5.

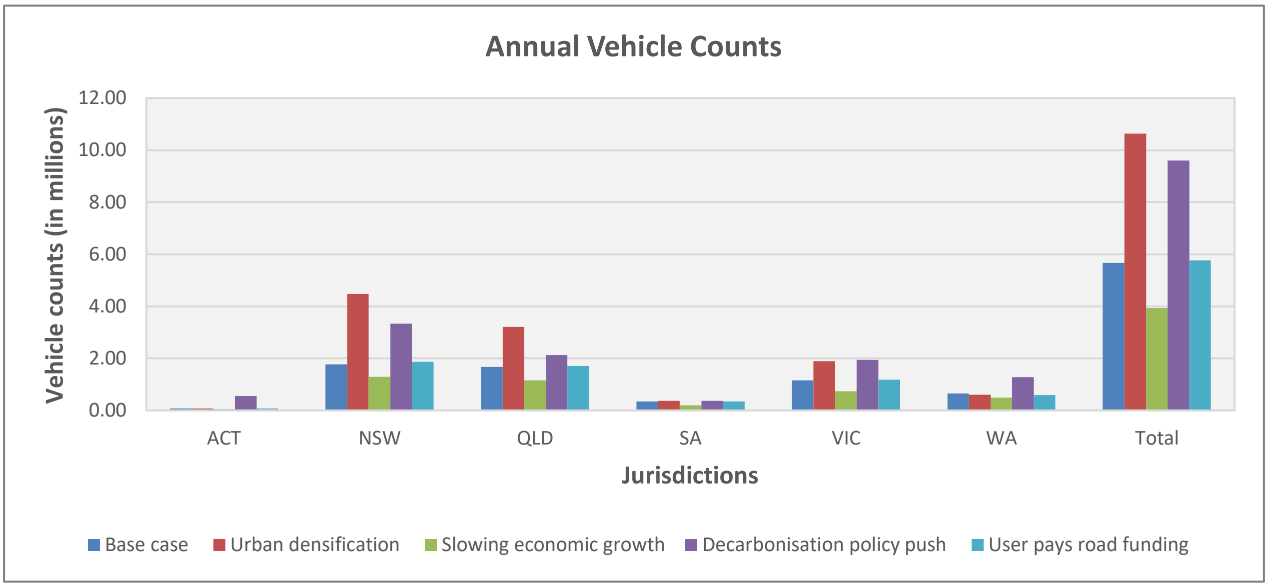
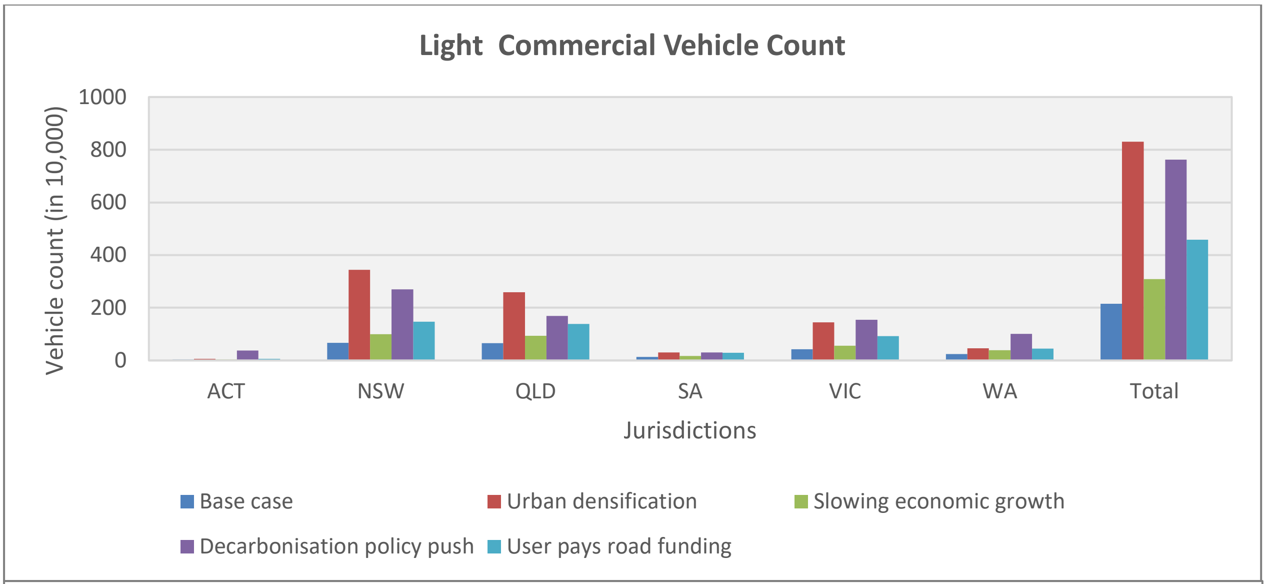
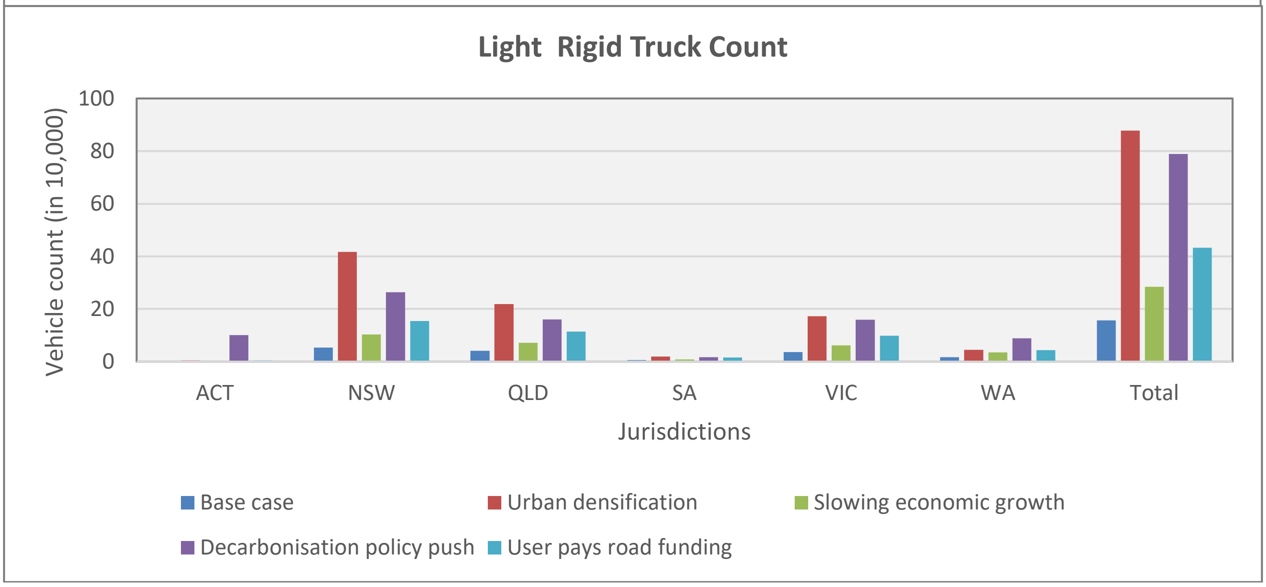
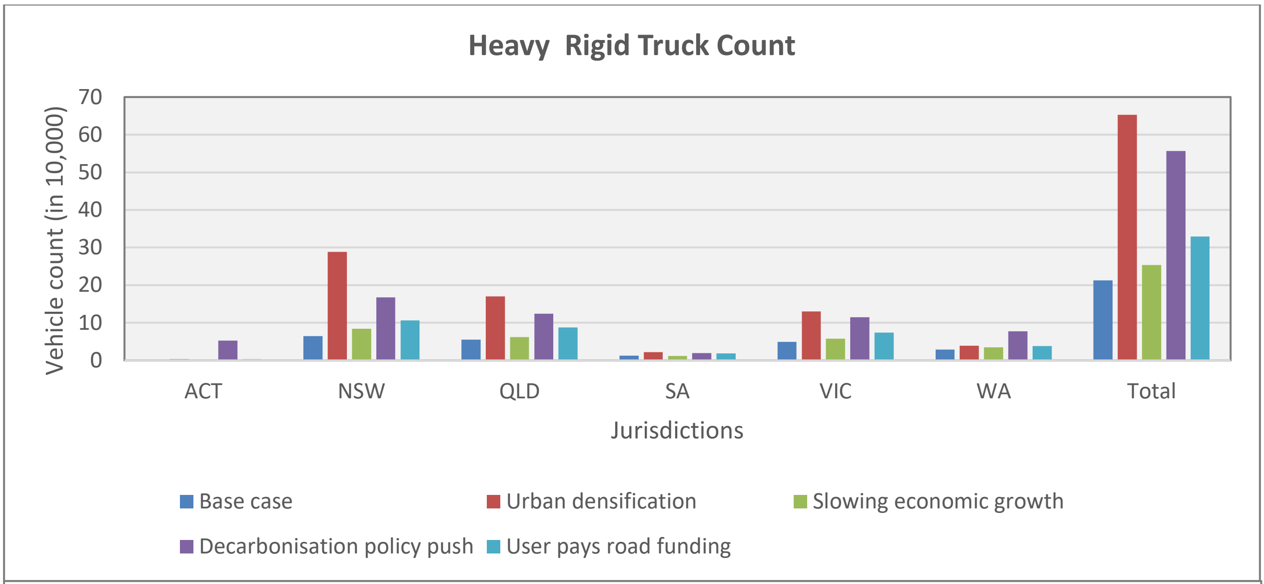


Figure 3.2. Annual vehicle counts (in millions) in urban areas across different transition scenarios (for the year 2041) [ACT = Australian Capital Territory; NSW = New South Wales; QLD = Queensland; SA = South Australia; VIC = Victoria; WA = Western Australia]


Light Commercial Vehicle Count
1000
800
600
400
200
0
Vehicle count (in 10,000)
ACT
NSW
QLD
SA
VIC
WA
Total
Jurisdictions
Base case
Urban densification
Slowing economic growth
Decarbonisation policy push
User pays road funding


Light Rigid Truck Count
100
80
60
40
20
0
Vehicle count (in 10,000)
ACT
NSW
QLD
SA
VIC
WA
Total
Jurisdictions
Base case
Urban densification
Slowing economic growth
Decarbonisation policy push
User pays road funding



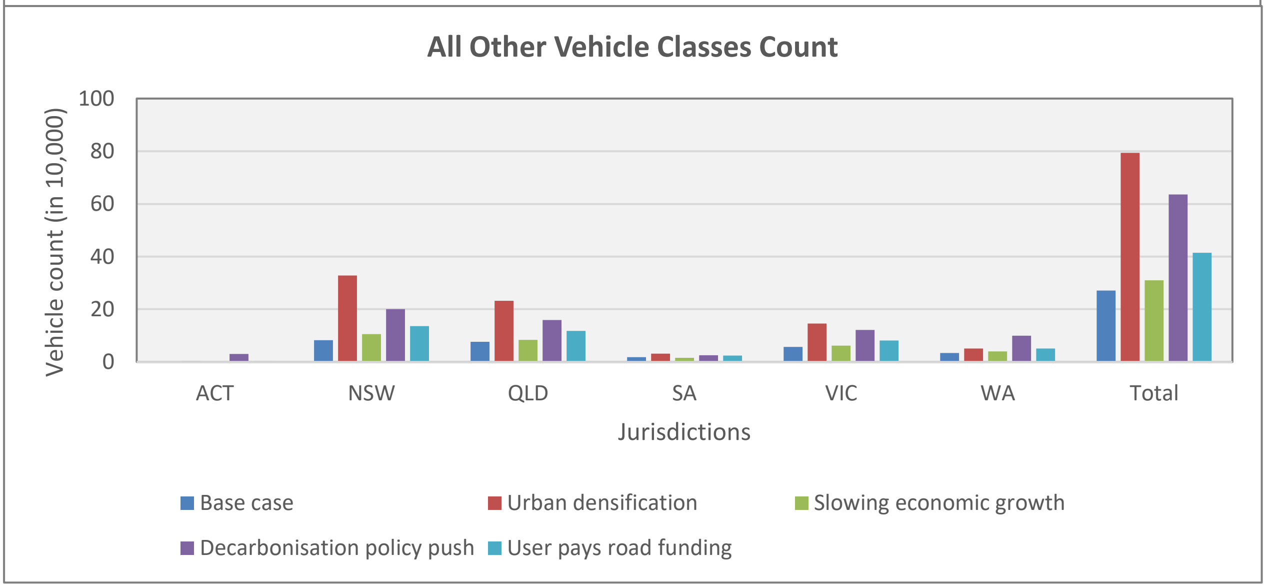


Figure 3.3. Annual vehicle counts by vehicle class (in 10,000) in urban areas across different transition scenarios (for the year 2041) [All other vehicle classes includes prime mover, semi-articulated trailers, and other vehicle class]

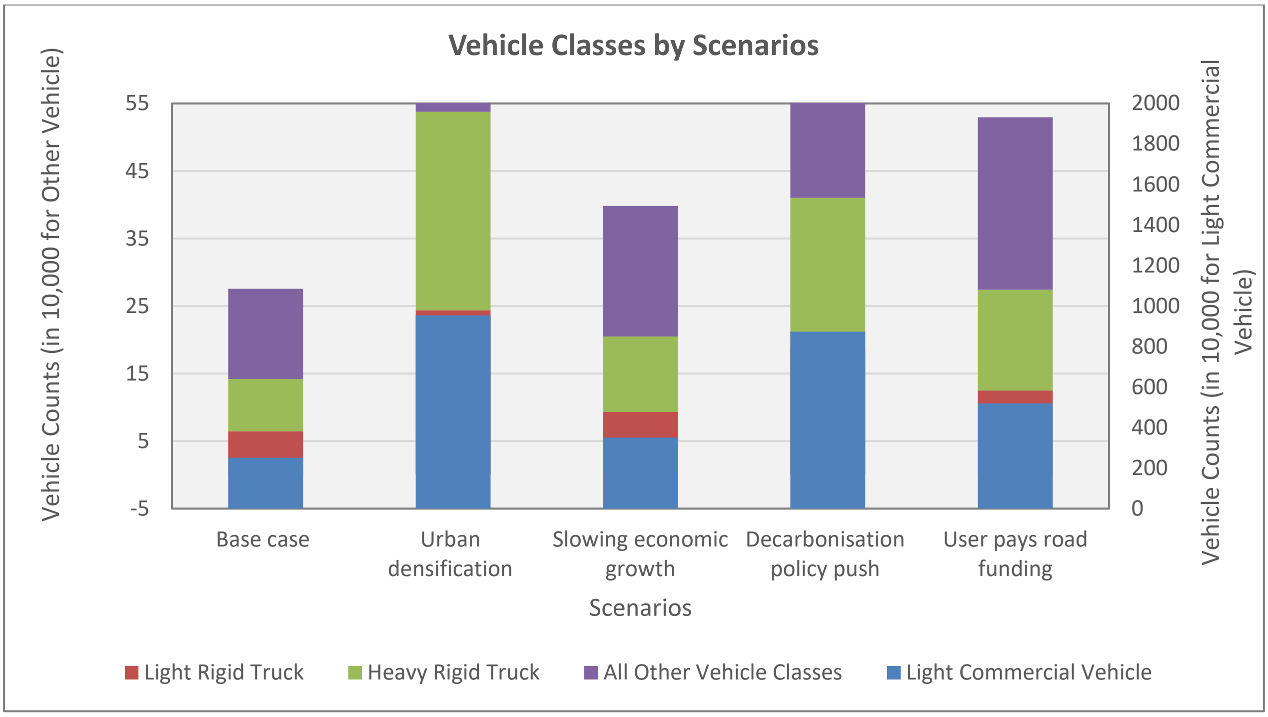


Figure 3.4. Comparison of annual vehicle counts by vehicle class (in 10,000) in urban areas across different transition scenarios (for the year 2041) [All other vehicle classes includes prime mover, semi-articulated trailers, and other vehicle class]

Table 3.3. Annual EV/Hybrid/Other fuel driven vehicle counts (in 10,000) in urban areas across different transition scenarios

Jurisdictions	Base case	Urban densification	Slowing economic growth	Decarbonisation policy push	User pays road funding
ACT	0.01	0.02	0.01	26.14	0.02
NSW	0.05	1.72	0.24	61.86	0.13
QLD	0.03	0.15	0.12	21.17	0.08
SA	0.01	0.03	0.02	9.19	0.03
VIC	0.13	0.58	0.32	32.82	0.35
WA	0.04	0.08	0.11	20.82	0.08
Total	0.27	2.57	0.82	171.99	0.70

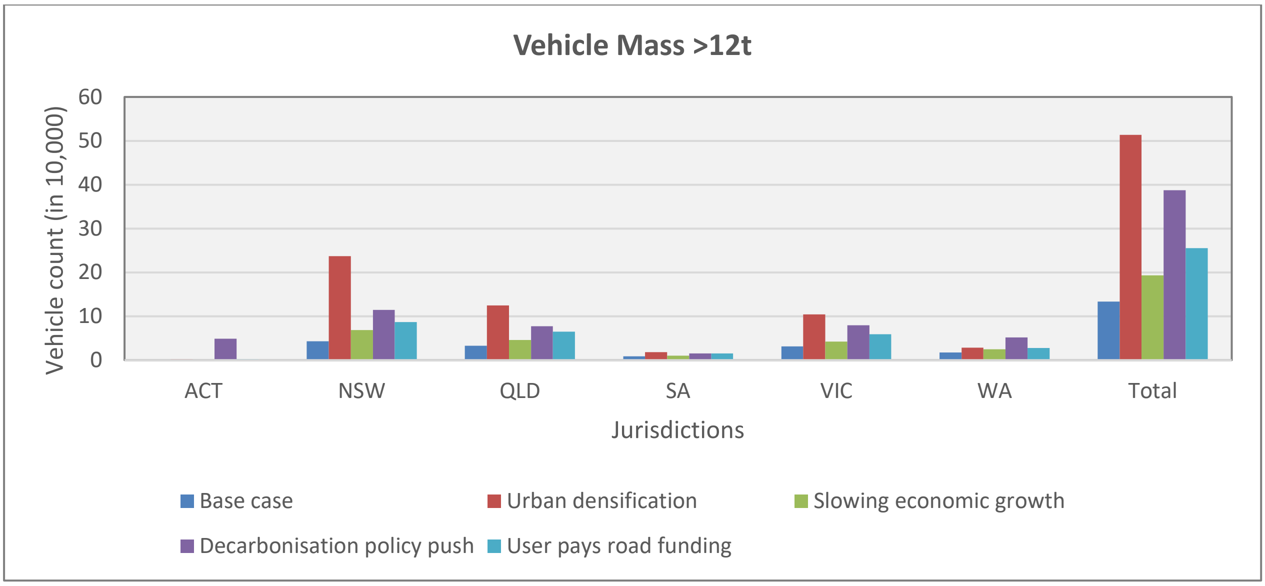


Figure 3.5. Annual vehicle counts for vehicles which are >12t (in 10,000) in urban areas across different transition scenarios (for the year 2041)

The findings from the transition scenario analysis are summarised below[8] –

- Across all vehicle types, the annual vehicle counts were found to be higher in the urban densification scenario. The second highest annual vehicle counts were found from the decarbonisation policy push scenario. The results signify the greater influence of urban densification and economic growth on freight and commercial service activities.
- The percentage of light commercial vehicles were found to be marginally higher in the decarbonisation policy push and user pays road funding scenarios relative to base case scenario. Moreover, the percentage of heavy rigid truck is found to be lower in all scenarios relative to base case scenarios. The results are perhaps indicating higher level of growth in small payload and urban delivery activities by smaller vehicles and are resulting from increased commercial activities relevant to these freight services.
- As expected, the percentage of EV/hybrid/other fuel driven vehicles were found to be highest in the decarbonisation policy push scenario. This scenario imposes the highest level of restrictions on the ICE vehicles while also aiding the EV uptake policies at the greater levels relative to other scenarios. The result signifies the importance of implementing EV related policy measures and supporting higher level of EV supply to aid the acceleration of these alternate fuel driven vehicles in the Australian freight and commercial service sectors.
- The percentage of the vehicles with >12t mass were found to be marginally lower in the user pays road funding scenario relative to the base case scenario. In stakeholder consultation, impact of location of distribution centre and multi-modal facilities were identified as one of the major uncertainties relevant to the new infrastructure developments. The user pays road funding

[8] Percentage of vehicle counts by vehicle class and vehicle mass across different transition scenarios are presented in Tables C.1 and C.2, respectively in Appendix C. Percentage of EV/hybrid/other vehicle type counts across different transition scenarios are presented in Figure C.1 in Appendix C.

(scenario 4) focuses mainly on the infrastructure investments which were tailored towards distance-based charging regime. Thus, as portrayed in scenario 4, such user-based road charge might be encouraged higher level of commercial activities within the area to mitigate longer travel distance from other locations. as such, higher level of commercial activities in these areas are likely to contribute to higher share of light commercial vehicles for delivering the small payloads, and hence, the share of heavy vehicles in such scenarios are likely to decrease.

Chapter 4: CONCLUSIONS

The overarching aim of the Urban Freight Shifts (UFS) project was to develop a data-driven and evidence-based forecasting tool to inform future city planning, regulation and charging associated with the current and emerging UF and CS vehicle trends. The integrated UFS forecasting tool was developed as an "Excel Workbook" and was delivered along with this report.

The report also presented different transition scenarios analyses outcomes. The results from transition scenario analyses showed the greater influence of urban densification and economic growth on freight and commercial service activities. Moreover, the scenario analysis signified the importance of implementing EV related policy measures and ensuring higher level of EV supply to support the acceleration of alternate fuel driven vehicle uptake in the Australian freight and commercial service sectors. Moreover, it was found that a higher level of commercial activities is likely to contribute towards higher percentage of light commercial vehicles registration for delivering the small payloads and urban deliveries. Hence, the share of heavy vehicles in such scenarios were found to be lower. These results demonstrated the interplay of supply-chain in the freight and commercial service vehicle fleet mix ambition.

REFERENCES

BITRE. (2019). Australian aggregate freight forecasts – 2019 update, Research Report 152. Bureau of Infrastructure, Transport and Regional Economics (BITRE). Australian aggregate freight forecasts – 2019 update (bitre.gov.au).

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APPENDIX A: ANALYTICAL FRAMEWORK

Regression models were estimated to examine the effects of different explanatory (independent) variables on number of Urban Freight (UF) and Commercial Service (CS) vehicles registered by different features (annual vehicle count, vehicle class, fuel type and vehicle mass). These regression models were estimated by employing different econometric frameworks. Econometric model is a data-driven, evidence-based, and strategic tool for developing analytical framework focusing on performance measures. To date, it remains the most widely used and most effective analytical framework for planning, prioritisation, evaluating and monitoring different investment programs/policies, and, hence, allows us to develop an integrated decision support tool capturing different components of policy decision process. Thus, the Project Team proposed to develop a set of macro-level predictive models of annual vehicle count models by different vehicle features (at the postal area level) building on the theory of econometric models. The econometric formulations for the developed models are presented in this section.

ECONOMETRIC FORMULATIONS

In developing the predictive models for examining the market trends in UF and CS vehicles, 4 different models were estimated Econometric formulations for these modelling frameworks are presented in the following sections.

Linear Regression Model

For developing annual vehicle count models, a linear regression (LR) framework was employed with logarithmic transformations of the dependent variable (annual vehicle counts per postal area). Let $i\ (i = 1,2,3, \dots, N)$ be an index to represent postal area, and V_i be an index to represent the annual vehicle counts in a postal area. Then, the equation system for modelling vehicle counts may be written as follows:

$$\ln (V_i) = \boldsymbol{x}_i\boldsymbol{\beta} + \varepsilon_i, \text{ for } i = 1,2, \dots \dots \dots, \text{N} \qquad 1.$$

where, $i\ (i = 1,2, \dots \dots \dots, N)$ represents the observations, $\boldsymbol{x_i}$ is a vector of exogenous variables, $\boldsymbol{\beta}$ is a vector of unknown parameters to be estimated (including a constant), ε_i is an idiosyncratic random error term assumed independently normally distributed with variance λ_i^2. Maximum likelihood approach was used for estimating the regression model parameters as defined in Equation 1.

Multinomial Logit Fractional Split Regression Model

For developing annual vehicle count model by vehicle class and by fuel type, the multinomial fraction split approach. Let η_{mn} be the fraction of vehicle counts by fuel type/vehicle class $(m = 1,2,3, \dots, M)$ in a postal area $i(i = 1,2,3, \dots, N)$ for a specific year, such that

$$0 \leq \eta_{mn} \leq 1 \qquad \sum_{m=1}^{M} \eta_{mn} = 1 \tag{2.}$$

Let the fraction η_{mn} be a function of a vector x_{mn} of relevant explanatory variables associated with attributes of postal area i. The econometric specification for multinomial logit FS approach can be defined as:

$$E[y_m|x] = G_m(x;\delta)$$
$$0 < G_m(\cdot) < 1 \qquad \sum_{m=1}^{M} G(\cdot) = 1 \tag{3.}$$

where $G_m(\cdot)$ is a predetermined function. The properties specified in Equation 3 for $G_m(\cdot)$ warrant that the predicted fractional vehicle count by fuel type will range between 0 and 1, and will add up to 1 for each postal area. For the multinomial FS approach, the Equation 3 can be rewritten as:

$$E(\eta_m|x) = G_m(x;\delta) = \frac{\exp(x\delta_m)}{\sum_{m=1}^{M} \exp(x\delta_m)}, \quad m = 1, \dots, M \tag{4.}$$

Given the probability expression above, the quasi-likelihood function is written as follows:

$$L_q(\delta) = \prod_{m=1}^{M} G_m(x_n;\delta)^{\eta_{mn}} \tag{5.}$$

Finally, the quasi log-likelihood function for the sample is defined as: $\mathcal{L}(\delta) = \sum_{n=1}^{N} \ln (L_q(\delta))$

The model estimation is undertaken by maximizing the quasi log-likelihood function based on a routine in Gauss matrix programming language.

Ordered Logit Fractional Split Regression Model

For developing regression model for vehicle count by vehicle mass, ordered logit fractional split approach is used. Let $q(q = 1,2,3, \dots, N)$ be an index to represent postal area, and let $k(i = 1,2,3, \dots, K)$ be an index to represent GVM category. The latent propensity equation for GVM category at the qth postal area can be written as:

$$g_q^* = \boldsymbol{\omega} \boldsymbol{z}_q + \xi_q \tag{6.}$$

This latent propensity g_q^* is mapped to the actual GVM category proportion g_{qk} by the ψ thresholds $(\psi_0 = -\infty$ and $\psi_K = +\infty)$. $\boldsymbol{z}_q$ is a vector of attributes (not including a constant) that influences the propensity associated with GVM category. $\boldsymbol{\omega}$ is a corresponding vector of mean effects. ξ_q is an idiosyncratic random error term assumed to be identically and independently standard normal distributed across postal area q for a specific year.

The model cannot be estimated using conventional Maximum likelihood approaches. Hence, we resort to quasi-likelihood based approach for our methodology. The parameters to be estimated in the Equation 6 are $\boldsymbol{\omega}$, and ψ thresholds. To estimate the parameter vector, we assume that -

$$E(y_{qk} \mid z_{qk}) = H_{qk}(\alpha,\psi), 0 \le H_{qk} \le 1, \sum_{k=1}^{K} H_{qk} = 1 \quad 7.$$

H_{qk} in the model takes the ordered logit probability (P_{qk}) form for GVM category k defined as:

$$P_{qk} = \left\{ G\left[\psi_k - \alpha_q' z_q\right] - G\left[\psi_{k-1} - \alpha_q' z_q\ \right] \right\} \quad 8.$$

The proposed model ensures that the proportion for each GVM category is between 0 and 1 (including the limits). Then, the quasi-likelihood function, for a given value of vector may be written as:

$$L_q(\alpha,\psi) = \prod_{k=1}^{K} \left\{ G\left[\psi_k - \alpha_q' z_q\right] - G\left[\psi_{k-1} - \alpha_q' z_q\ \right] \right\}^{d_{qk}} \quad 9.$$

where G(.) is the cumulative distribution of the standard normal distribution and d_{qk} is the proportion of vehicle in GVM category k. The model estimation is undertaken using routines programmed in Gauss matrix programming language.

APPENDIX B: EV FAST CHARGING POINT PREDICTION

The historical data on EV fast charging points were collected from the open-source database for the year 2017 to 2022. In the selected urban areas, between 2017 to 2022, the new EV fast charging installation ranged from 71 to 167, whereas year 2020 had the highest number of installations (167). The average number of new charging points installed in the last three years were 142. Therefore, 145-150 new charging points were assigned randomly in future years by applying uniform distribution approach across different postal areas.

EV vehicle adoption is still in its early stages in Australia. It may result in a high number of charging points installation in the initial phase which is likely to decrease over time. In the random assignment, it was assumed that EV charging stations and petrol stations are competitive. The acquired data on petrol stations shows that there are currently 2,575 petrol stations in the study area. Hence, it can be concluded that there would be at least 5,100 charging points (2,550 fast charging stations) installed before the rate of new charging point installations decreases or halts. Based on these assumptions, the projected number of fast charging stations is identified to be 3,500 at the end of 2041. Therefore, 145-150 charging points per year are randomly assigned across different postal areas. The projected EV fast charging points are presented in Figure B.1. to be sure, we have adopted a simplistic approach in assigning EV fast charging points since we are focusing on area. A robust approach of EV fast charging point assignment would be required for network level analysis, which is beyond the scope of this project.

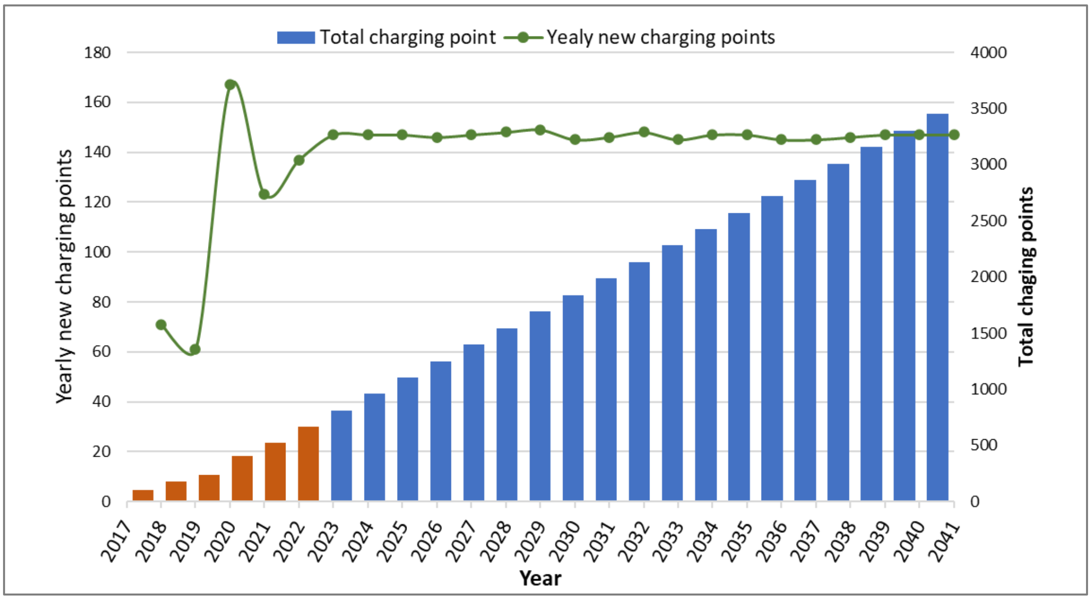

Figure B.6. Predicted EV fast charging points (year 2022 to 2041)

APPENDIX C: URBAN FREIGHT AND COMMERCIAL SERVICE VEHICLE TRENADS ACROSS TRANSITION SCENARIOS

Table C.1. Percentage of vehicle counts by vehicle class across transition scenarios

VEHICLE CLASSES	PERCENTAGE OF VEHICLE COUNTS BY VEHICLE CLASS WITHIN EACH SCENARIO				
	TRANSITION SCENARIOS				
	Base case	Urban densification	Slowing economic growth	Decarbonisation policy push	User pays road funding
Light Commercial Vehicles	77.12	78.12	78.43	79.36	79.58
Light Rigid Trucks	5.59	8.26	7.23	8.22	7.51
Heavy Rigid Trucks	7.61	6.14	6.45	5.80	5.71
Prime Movers	1.48	1.14	1.22	1.01	1.12
Semi Articulated Trailers	6.05	4.69	4.89	4.07	4.47
Other Vehicle Classes	2.16	1.64	1.77	1.54	1.62
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

Figure C.7. Percentage of EV/hybrid/other vehicle counts across transition scenarios

Transition Scenario Analyses

VEHICLE CLASSES	PERCENTAGE OF VEHICLE COUNTS BY VEHICLE CLASS WITHIN EACH SCENARIO				
	TRANSITION SCENARIOS				
	Base case	Urban densification	Slowing economic growth	Decarbonisation policy push	User pays road funding
Light Commercial Vehicles	77.12	78.12	78.43	79.36	79.58
Light Rigid Trucks	5.59	8.26	7.23	8.22	7.51
Heavy Rigid Trucks	7.61	6.14	6.45	5.80	5.71
Prime Movers	1.48	1.14	1.22	1.01	1.12
Semi Articulated Trailers	6.05	4.69	4.89	4.07	4.47
Other Vehicle Classes	2.16	1.64	1.77	1.54	1.62
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**

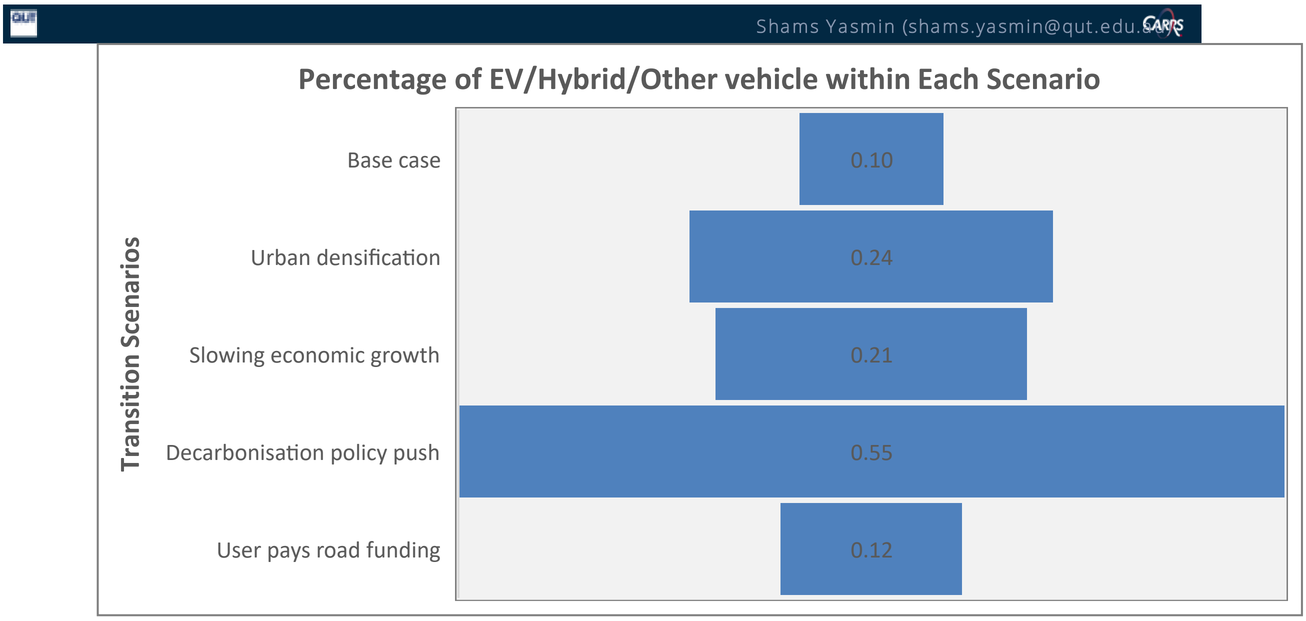

Table C.2. Percentage of vehicle counts by vehicle mass across transition scenarios

GVM CATEGORIES	PERCENTAGE OF VEHICLE COUNTS BY VEHICLE MASS WITHIN EACH SCENARIO				
	TRANSITION SCENARIOS				
	Base case	Urban densification	Slowing economic growth	Decarbonisation policy push	User pays road funding
0-4.5t vehicle	90.08	90.07	89.80	91.64	90.75
>4.5-8t vehicle	2.33	2.30	2.39	1.96	2.18
>8-12t vehicle	2.79	2.77	2.86	2.34	2.60
>12-20t vehicle	1.77	1.77	1.81	1.49	1.65
>20-28t vehicle	2.22	2.25	2.28	1.88	2.06

>28t vehicle	0.82	0.83	0.85	0.69	0.75
Total	**100.00**	**100.00**	**100.00**	**100.00**	**100.00**