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

Project No: 6-005

URBAN FREIGHT SHIFTS

Summary Report: Market Analysis of Current Urban Freight and Commercial Service Vehicle Trends

November 2022

Australian Government
Department of Infrastructure, Regional Development and Cities

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Project No: 6-005

URBAN FREIGHT SHIFTS

Summary Report: Market Analysis of Current 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).

November 2022

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 charging associated with the current and emerging urban freight (UF) and commercial service (CS) vehicle trends.** The current report presents 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 final report will present the complete analysis of impacts and trends including the forecasting tool.

Stakeholder consultations

Relevant stakeholders were consulted to identify the existing and possible emerging trends in UF and CS vehicles through interviews and an online survey. The key findings were:

- Increases in freight volumes are driven by population increases and housing construction.
- Urban densification has resulted in congestion on urban routes to local customers and to ports, with inadequate investment in road and rail infrastructure upgrades contributing significantly to the problem.
- Increasing costs and reduced availability of land for large distribution centres near city centres, is contributing to more steps in the supply chain (e.g., deliveries from distribution centres to fulfilment centres or "dark stores" or microfreight hubs before last-mile delivery).
- Diversification of the freight vehicle fleet is occurring with growth both at the small and very ends.
- Growth in electric light commercial and small rigid trucks.
- Adoption of new fuel and safety technologies by larger fleets more than smaller operators.
- Relaxation of curfews and more off-peak deliveries to both businesses and end-users.

The stakeholders identified the following escalating trends in the UF and CS sectors:

- The growth in small payload, urban delivery, particularly of hot foods and groceries and online purchases to customers' homes.
- The influence of company and government environmental policies on uptake of alternative fuels (EVs and hydrogen fuelled vehicles).
- Disruptions to supply routes (both rail and road) because of increased frequency of natural disasters leading to changes in the mode used and the choice of port to use.
- Use of small electric vehicles for urban freight delivery.

Quantitative analyses of UF and CS vehicle trends

Exploratory analyses were undertaken to develop an understanding of current market trends in numbers of Urban Freight (UF) and Commercial Service (CS)vehicles, distance travelled and vehicle operating costs. For this project, "urban areas" were defined as the 1,030 postal areas completely or partly within major cities of Australia (according to the Remoteness Index or ARIA, Australian Bureau of Statistics 2016b).

The largest shift in UF and CS vehicles was the move from petrol- (down by approximately 400,00 or 30%) to diesel-engined (up by approximately 100,000 or 19%) light commercial vehicles between 2017 and 2021. While three-quarters of the distance travelled by UF and CS vehicles in capital cities involves light commercial vehicles, it is important to note that about 40% of travel is for private and commuting purposes. Thus, only part of this large shift may actually be related to their use in UF and CS.

The exploratory analyses showed that Utilities outnumber other UF and CS vehicle types and they have grown by about 4% per year over 2017 to 2021. Panel vans are the second largest vehicle type but their numbers were reasonably stable. Among the most important freight vehicles, the average growth rate was highest for light rigid trucks (6.1% per year), followed by semi (articulated) trailers (4.1% per year). Lower annual growth rates occurred for prime movers (between 2 and 4% per year) and heavy rigid trucks (between 1 and 4% per year).

The age of the vehicle fleet is an important constraint on the prevalence of alternative fuels which have only been available in recent years. In 2021 only 11.9% of panel vans, 13.1% of utilities, 15.3% of light rigid trucks and 9.0% of heavy rigid trucks were 5 years old or newer.

It is difficult to separate electric vehicles (EVs), hybrid and “other fuel type” (which includes biodiesel) in the ABS data. Less than 1% of UF and CS vehicles were EV/hybrid/other fuel types and the proportion of UF and CS vehicles that were EV/hybrid/other **did not change** to a statistically significant degree from 2016 to 2020. Panel vans experienced the largest percentage growth in EV/hybrid/other fuel vehicles (from 0.04% in 2016 to 0.07% in 2020).

In general, the findings from the stakeholder consultations and the quantitative analyses were consistent. The quantitative analyses based on newer vehicles appeared to be somewhat more aligned to the stakeholder comments. There were, however, some stakeholder comments which were not able to be tested or were not supported by the quantitative findings.

The stakeholder comments and the quantitative analyses both underlined the diversity of UF and CS vehicle fleets, with different mixes of vehicle types among jurisdictions and different trends for different vehicle types.

Conclusions

In developing the integrated forecasting tool for UF and CS vehicle trends, this report summarises the initial results from the stakeholder consultations and the quantitative analyses of UF and CS vehicle trends. The report presents:

- Results from stakeholder consultations;
- Operating costs of UF and CS vehicles; and
- Results from quantitative analyses of UF and CS vehicle trends.

In addition, a data collection and verification framework and establishment of a future UF and CS vehicle trends dataset was developed.

In the next phase of the project, a forecasting tool will be developed by using the outcomes from market trend analyses. The outcomes for market trend analyses will form the “base case” scenario for developing and estimating the transition scenarios of UF and CS vehicle trends.

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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
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 forecast urban freight to grow by nearly 60% over the 20 years to 2040 (Transport Infrastructure and Council, 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. Factors when considering these trends include understanding:

- The balance of smaller and larger vehicles used by freight and other commercial businesses currently and in the next few years, given that light commercial vehicles (e.g., small trucks and vans) less than 4.5tonnes (t) gross vehicle mass (GVM) do not require drivers to hold truck licences and the operators of these vehicles do not pay heavy vehicle road user charges. However, larger vehicles pay less fuel excise due to fuel tax credits.
- The impacts of increased volumes of light commercial vehicles on urban amenity need to be planned for (such as kerbside access, curfews, congestion).
- The effects of fewer large vehicle movements on urban road maintenance costs, given the impact of vehicles under approximately 10t GVM on road wear and tear is not significant, and
- The factors influencing uptake in electric vehicles (EVs), current uptake rates (given EVs do not pay fuel excise), their impact on urban amenity and cost to freight companies in urban last mile freight.

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 understanding of the changes to road use by heavy vehicles and related heavy vehicle safety, as well as flow on effects to infrastructure planning and investment, and vulnerable road users.

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 charging 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 outcome of this project will provide planners and decision makers with a basis for an evidence-based platform to create future scenarios.

The forecasting tool will be developed by integrating the outcomes from the following Research Objectives (RO):

- **RO 1:** Consult stakeholders to develop measures of UF and CS vehicle trends.
- **RO 2:** Analyse current UF and CS vehicle market trends.
- **RO 3:** Develop demand mechanism indicators of current and emerging UF and CS vehicle trends.
- **RO 4:** Develop traffic-stress indicators relevant to UF and CS vehicle trends.
- **RO 5:** Develop and evaluate UF and CS demand transition scenarios.

1.2.1 Structure of the Report

Report 1 has the following structure:

Chapter 2: Summarises the findings from the existing scientific literature on UF and CS analytics.

Chapter 3 (Addresses RO 1): Presents the findings from the stakeholder consultations.

Chapter 4 (Addresses RO 2): Presents the data and summarises the exploratory analysis of UF and CS vehicle data and cost components.

Chapter 5 (Addresses RO 2): Presents the regression analyses results of UF and CS vehicle trends.

Chapter 6: This chapter presents the conclusions from the stakeholder consultations and quantitative market trend analyses.

Chapter 2: LITERATURE REVIEW

The literature on recent and predicted shifts in Urban Freight (UF) and Commercial Services (CS) and the literature on modelling urban freight were reviewed to inform the later modelling of recent changes in Australia and selection of future scenarios.

2.1 SUMMARY OF FACTORS INFLUENCING URBAN FREIGHT

The factors influencing urban freight identified in the existing literature can broadly be grouped into: socio-economic attributes, land use features, transport infrastructures, built environment features, presence of key facilities, and other variables. The factors and the references are summarised in Table 2.1. In addition, Wang and Hu (2012) indicated that mode choice by the commercial sector is travel-specific, territory dependent, cargo sensitive and varies by shipment companies. A survey of freight mode choice in 11 African countries (Konstantinus and Zuidgeest 2019) found that punctuality, transport cost, damage risk, service frequency, and transit time play a crucial role in freight mode selection.

2.2 STUDIES OF VEHICLE COMPOSITION BY FUEL TYPE

Technological advancements and new fuel types have the potential to cause shifts in vehicle composition or modal shift. However, several authors have noted that changes are more likely to occur for cars than freight and commercial services vehicles (Leard, McConnell and Zhou 2019; Samimi, Kawamura, and Mohammadian 2011). Several studies have concluded that companies operating in major cities which face higher congestion and haul deliveries over short distances, are more likely to adopt the new fuels (hybrid electric or fully electric) (Queensland Transport and Logistics Council and Movement (Jan 2022), Stinson, Auld, and Mohammadian 2020; Zhang et al. 2019) as are larger companies (Stinson et al. 2020).

According to the International Energy Agency (IEA 2022), the global share of electric heavy duty vehicles is 0.1% (66,000 vehicles), of which 90% are in China. However, electric light commercial vehicles sales have increased globally by 70% in 2021, where, China, Europe, and Korea have respectively 86k, 60k, and 28k light commercial EVs. The Australian-based company, SEA Electric recently announced to double its production of locally assembled electric trucks (Quick Sep 2022) indicating a higher demand for light rigid trucks. The company will now assemble 8 trucks per day, or 2080 annually. The SEA Electric assembling facility in North America has capacity of 30,000 trucks annually. In addition, Ford started producing electric vans in January 2022 in North America.

Table 2.2 List of explanatory variables identified from existing literature

BROAD CATEGORIES	VARIABLES	STUDIES
Socio-economic attributes	Employment	Dixit et al. 2022; Ahmed and Roorda 2022a; Holguín-Veras, Sánchez-Díaz, and Browne 2016; Pani et al. 2018; Venkadavarahan and Marisamynathan 2021; Ahmed and Roorda 2022b; Sánchez-Díaz, Holguín-Veras, and Wang 2016
	Population	Keya et al. 2021
	Household income	
Land use features	Urban area in origin/destination zone	Keya et al. 2021
	Location/accessibility of urban freight facilities – a shopping mall, warehouses, distribution centres.	Venkadavarahan and Marisamynathan 2021; Keya et al. 2021
Transport infrastructures	Length of motorway/highway /railway in a region	Uddin, Anowar, and Eluru 2021; Sánchez-Díaz, Holguín-Veras, and Wang 2016
	Distance to primary network and truck routes	Sánchez-Díaz, Holguín-Veras, and Wang 2016
	Large traffic generators	
Built environment features	Number of industries (different sizes) in a zone – including retail shops, restaurants or cafes, factory outlets	Dixit et al. 2022; Sánchez-Díaz, Holguín-Veras, and Wang 2016
	Land market value, number of businesses in a zone, and their geographic locations	Sánchez-Díaz, Holguín-Veras, and Wang 2016
	Gross floor area of facilities	Pani et al. 2018; Venkadavarahan and Marisamynathan 2021
Presence of key facilities	Presence of intermodal terminals (at origin and destination)	Keya et al. 2021
	Presence of airport (national or international) or seaport	
Other variables	Number of on or off-street loading/unloading bays in a zone/region (OR the number of parking locations	Keya et al. 2021; Mrazovic et al. 2017
	Distance between origin and destination, or origin-destination location	Ahmed and Roorda 2022b

Several authors have made predictions regarding when price parity will be achieved between conventional and electric light commercial vehicles. The Boston Consulting Group (Pohlkamp et al. 2022) predicted that EV and ICE based light commercial vehicles would have similar total cost of ownership over lifetime of vehicle by end of 2023. The prices would mainly decrease by reducing the cost associated with battery pack. The report further predicted that 55%, 35%, and approximately 5% of light commercial vehicles, light rigid trucks, and heavy rigid trucks respectively, would comprise of EV at the end of this decade The report also claimed that long distance inter-city commercial vehicles may not be suitable for EV by end of this decade due to long range, trade-off between payload and battery load, and lack of highway charging infrastructure. However, few studies have reported real-world comparisons of the ownership cost of electric and ICE heavy vehicles due to the limited time after manufacturing of electric heavy vehicles.

The challenges to the adoption of electric trucks identified from an examination of the literature were:

- Technical
    - Battery weight
    - Longer charging time
    - Charging infrastructure
- Economical
    - High initial cost
    - Uncertain repair costs and time
    - Uncertainty in residual value
    - High total ownership cost
    - Reduced operation flexibility
- Market maturity
    - Uninformed consumer
    - Rapid changes in the EV technology
    - Lack of availability of models, government regulations
    - Culture
    - Industry confidence
- Regulation
    - Not allowing wider trucks (Electric Vehicle Council and Australian Trucking Association 2022; Electric Vehicle Council Oct 2022)
    - Weight restrictions (Electric Vehicle Council and Australian Trucking Association 2022; Electric Vehicle Council Oct 2022)
    - Lack of monetary concessions (e.g., reductions in stamp duty, registration cost, and direct subsidies)

Another author noted that predictions of electric vehicle growth have assumed that materials needed for electric vehicles, such as lithium, do not face global shortage (Purtill 2022). The International Council on Clean Transportation (ICCT Jan 2022) pointed out plug-in hybrid EVs may not be suitable for light commercial vehicles or light rigid trucks due to presence of dual powertrains, which increase the total cost of the vehicle as compared to fully ICE or electric powertrains.

Some company sustainability policies promote the uptake of alternative fuels and vehicle types with lower fuel consumption. For example, Deutsche Post DHL aim to reduce their carbon emissions to net zero by 2050 (Deutsche Post DHL Group, 2019). They are using more than 10,000 electric StreetScooters for deliveries in Germany and are planning to expand their use across Europe. For heavier freight transport, they are investing in biofuels and hydrogen and synthetic fuels. Their ultimate goal is to “find the sweet spot between environmental performance, commercial viability and operational feasibility” (p.5).

Chapter 3: FINDINGS FROM STAKEHOLDER CONSULTATIONS

Consultations with relevant stakeholders were undertaken to identify the elements that are driving changes in urban freight (UF) and commercial service (CS) vehicle trends while also documenting the land-use and operational challenges. The consultations also sought to learn more about tasks for which connected and automated driving systems and drones are likely to be beneficial and are expected to have a major impact. The stakeholder consultations were conducted through interviews and an online survey.

3.1 METHOD

3.1.1. Stakeholder interviews

Participants who were known to have relevant experience or identified as being relevant through online searches were emailed invitations to participate in May 2022. The 12 interviews completed between May and July 2022 involved local and state government (*n* = 4), federal government (*n* = 2), academia (*n* = 1), logistics (*n* = 1), industry advisory bodies (n = 1), electric vehicles (*n* = 1) and microfreight organisations (*n* = 2). The question prompts and specific questions sought to gain participants' perceptions regarding trends in urban freight and commercial services transportation in the past 10 years and that they expect to occur in the next 10 years. This included changes in the type/volume of goods, the vehicles used and the regulatory environment. They were asked to focus on changes that were considered likely to persist.

3.1.2. Stakeholder survey

The researchers emailed invitations to complete the online survey and/or forward the invitation to other relevant people in May 2022. After few responses were received, an invitation was sent by the Department to approximately 300 contacts on a list maintained by the National Freight Data Hub and posted on their newsletter and 60 further invitations were sent to additional contacts of the project team in June 2022.

The survey questionnaire contained a core set of 23 multiple choice items addressing the same issues as in the stakeholder interviews (see Appendix A). There were only 13 responses to the survey and so responses from the interviews and surveys were reported together. Ethical clearance for the interviews and online survey was obtained from the Queensland University of Technology (QUT) (approval number: 5537).

3.2 RESULTS

3.2.1 Existing Trends in Urban Freight and Commercial Services

Stakeholders from smaller cities were less concerned about growth in traffic congestion or curfews and more concerned about reliability of supply, particularly in the context of increased frequency of climate-related natural disasters. The issues and tasks important for urban freight – and the vehicles used for freight transport - in the centre of cities differed quite a lot from the outer suburbs. The stakeholders consulted generally expected that the trends in the last 10 years would continue or, in some cases, escalate. The major findings with regards to the existing trends and trends in the last 10 years are[1]:

- Climate-related disasters were noted to cause disruptions for major long-distance freight rail lines which resulted in major short-term effects of forcing these products to be transported by road.
- Freight associated with primary industries (mainly mining and agricultural exports) had increased and that freight associated with local manufacturing had shrunk.
- International container transport is very much an urban freight task because most imported containers and many exported containers are transported by road less than 60 kms between the port and their origin or destination.
- Significant growth in small payload, urban delivery, particularly of hot foods and groceries to customers' homes and in online shopping were noted. Home deliveries are occurring both from stores and fulfilment centres. Delivery routes are becoming more efficient as a result of greater drop density. Fulfilment centres were developed in response to the huge growth in online ordering.
- Growth in small heavy vehicles (4.5-9 tonnes) and light commercial vehicles (less than 4.5 tonnes) were noted. However, a lot of urban freight is volume-constrained, rather than mass-constrained and that this has contributed to the uptake of larger trucks, although road and infrastructure limitations present challenges for use of larger trucks.
- There had been an increase in larger, more efficient vehicles being used for deliveries of large quantities to ports as a result of the application of Performance Based Standards (PBS).
- There is greater efficiency of delivery by cargo bikes in dense areas, compared to light commercial vehicles where about one-quarter of the time was spent circling to find parking and considerable driver time was consumed walking from the parking spot to the customer's premises.
- Relaxation of curfews and more off-peak deliveries were noted to both businesses and end-users.
- Light freight vehicles drive congestion, and the heavier vehicles drive wear on pavement condition. The traditional large rigid trucks and semi-trailers are now moving down to vans and light rigids, so the congestion aspect of light vehicles is becoming more important.
- Supply chains seemed to be coming longer, with an increased adoption of a "spoke and hub" approach, rather than direct delivery from the producer to the customer. Large vehicles serviced the hubs and smaller vehicles serviced the spokes.
- Volumes of freight were largely influenced by economic factors, with volumes increasing when the economy was strong and as a result of population growth (and a longer term move from rural to urban areas) and major construction projects.
- There had been an increase in total volumes of urban freight, with consequent competition for loading bay spaces and drop-off/pick-up places, particularly in the centres of cities.
- Ports remained important destinations for large volume loads, and consequently the largest vehicles being used for urban road freight.
- Urban freight originating from airports is a small but increasing part of the urban freight task, including new players such as Wellcamp and Moorabbin
- There had been very little take-up of electric freight vehicles because of the lack of interest and policy settings of the (former) Federal government and delays in orders of the limited models of electric vans available.

[1] A detailed narrative on the findings from the stakeholder consultations is contained in a supplementary document.

- E-trucks have had a purchase price premium and it has been hard to compare operating costs. Diesel excise discounts favour internal combustion engines. It was also noted that many operators assumed that one charger was needed for each e-truck, but this could be a wrong assumption.
- Greater adoption of new fuel and safety technologies by larger fleets more than smaller operators.
- Commercial services associated with construction is a major issue in urban areas with community backlash when trucks operate on roads where they are not permitted. Specific access plans are often developed but some drivers take shortcuts.
- Increases in driver-related costs had occurred because of new regulations and agreements, and that strengthening of health and safety rules had also impacted operations.

3.2.2 Anticipated Changes in the Next 10 Years

The major findings with regards to the anticipated changes in the last 10 years are:

- The growth in small payload, urban delivery, particularly of hot foods and groceries and online purchases to customers' homes might continue to increase.
- Continued increases in the delivery of small packages directly to consumers.
- The recent changes in origins and destinations would continue, particularly the increase in deliveries from large distribution centres on the edge of urban areas.
- Continuing residential densification would combine with home delivery to lead to more convenience stores and use of light commercial vehicles and rigid trucks.
- Land value will become a bigger issue in inner urban areas where customers have the choice to select in person and have it delivered versus buy online and pick it up. There is a potential that generational change will lead to this flipping.
- A significant shift to electrification was anticipated. Any new discovery in battery technology could make a step-change in the viability of e-trucks.
- Hydrogen fuelled vehicle would play a much smaller role than electrification in the next 10 years and that it might become more widespread over a longer time period.
- The push to net zero was identified as a factor encouraging transition to alternative fuels.
- Increases in urban densification would continue, with more formerly industrial suburbs becoming residential and forcing industry and distribution centres to move further from the city centre.
- The rise of the gig economy may continue and have significant effects on how urban freight is delivered.
- The total of purchase and operating costs over a period of years would continue to be the most important influence in decisions to purchase new trucks in the future.
- Current Australian Design Rules and mass and dimension limits could restrict the adoption of newer technologies and safety features.
- The uptake of autonomous trucks was not expected in next 10 years, although some individuals were supportive of truck platooning.
- Urban freight delivery by drones would start to become widespread by the end of the next 10 years. It was considered that they might be viable in niche situations in the future. It was expected that drone trials would continue.
- Small electric vehicles for urban delivery becoming widespread by the end of the next 10 years.
- An increase in electric motor scooters for urban food delivery and low freight loads.

A number of uncertainties were identified by the stakeholders which may influence the future trends:

- The extent to which working from home and the consequent changes in consumer behaviour will last.
- Whether just-in-time approaches will grow or whether recent supply shortages will encourage keeping more stock on hand.
- Economic cycles, because freight is a product of demand and supply.
- The impact of new infrastructure developments such as inland rail on the location of distribution centre and multi-modal facilities.
- The extent of improvements in fuel economy for ICE trucks.
- Costs and availability of electricity versus hydrogen.
- Government policies in terms of mass and dimensions for the largest trucks (also influencing take-up of safety features such as external sensors), definitions and regulations applying to small electric vehicles (e.g., cargo bike power limitations), depreciation (with shorter depreciation periods encouraging purchase of new vehicles), and incentives for use of alternative fuel vehicles.
- The extent to which gig economy models will influence urban freight (e.g., for large retailers) compared to current outsourcing of transport tasks.

3.3 IMPLICATIONS FOR QUANTITATIVE ANALYSES

The stakeholder consultations identified some factors for inclusion in the market trend analysis. These factors are summarised below with their availability in datasets noted in brackets.

- Effects of natural disaster (not available)
- Proximity to the city centre (available)
- Mining and agricultural exports have increased (land use can be a proxy for export level activities).
- Proximity to ports (available)
- Delivery of groceries/hot food (household density can be used as a surrogate)
- Rental cost for retail space (not available)
- Density of residential areas (available)
- Dwelling types (available)
- Safety concerns (available and will be generated in the second phase of the project)
- Major construction project (not available)
- Population (available)
- Economic indicators (available, employment and income will be used as surrogates)
- Relocations between urban and rural areas (not available)
- Overseas travel (not available)
- Online shopping (not available)
- Number of distribution centre/stores/fulfillment centre/home (not available)
- Airports (available)
- Parking space (available, building footprint will be used as a surrogate)
- Road type (available)
- Operating cost (available, computed values are presented in Chapter 4)

Chapter 4: EXPLORATORY ANALYSES

Exploratory analyses were undertaken to develop an understanding of current market trends in numbers of Urban Freight (UF) and Commercial Service (CS)vehicles, distance travelled and vehicle operating costs.

For this project, "urban areas" were defined as the 1,030 postal areas completely or partly within major cities of Australia (according to the Remoteness Index or ARIA, Australian Bureau of Statistics 2016b) because these locations have the highest population density and are likely to have the highest UF and CS activities (and ABS data are available for these areas).

4.1 NUMBERS OF REGISTERED VEHICLES

For the market trend analysis, the vehicle registration data available in the ABS Motor Vehicle Census (MVC) 2017 to 2021 were used. The census year reflects the vehicles registered in the earlier calendar year. The annual numbers of vehicles by postal area formed the basis for market trend analysis. The UF and CS vehicle fleet were considered in terms of 10 of the 27 MVC vehicle type categories (see Appendix B, Tables B1 and B2). Data were extracted for postal area, state, vehicle type, fuel type, and GVM.

Figure 4.1 summarises the numbers of UF and CS vehicles registered in urban areas between 2017 and 2021 (also see Appendix B, Table B3). It shows that:

- Utilities outnumber other UF and CS vehicle types and they have grown by about 4% per year over this period
- Panel vans are the second largest vehicle type but their numbers were reasonably stable
- Among the most important freight vehicles, the average growth rate was highest for light rigid trucks (6.1% per year), followed by semi (articulated) trailers (4.1% per year).
- Lower annual growth rates occurred for prime movers (between 2 and 4% per year) and heavy rigid trucks (between 1 and 4% per year).

4.1.1 Registered Vehicles by Fuel Type

The age of the vehicle fleet is an important constraint on the prevalence of alternative fuels which have only been available in recent years. For example, in 2021 only 11.9% of panel vans, 13.1% of utilities, 15.3% of light rigid trucks and 9.0% of heavy rigid trucks were 5 years old or newer.

Figure 4.2 shows the numbers of UF and CS vehicles registered in urban areas by fuel type in the MVC data for 2017 to 2021. Appendix C Table C4 in shows that 40% of light commercial vehicles (panel vans and utilities) were petrol-powered in 2017 which fell to 29% in 2021. It is difficult to separate electric vehicles (EVs), hybrid and "other fuel type" (which includes biodiesel) in the data. Nevertheless, the following comments can be made:

- Less than 1% of UF and CS vehicles were EV/hybrid/other fuel types.
- Panel vans experienced the largest percentage growth in EV/hybrid/other fuel vehicles (from 0.04% in 2016 to 0.07% in 2020)

- While utilities comprised the largest number of EV/hybrid/other fuel types, they did not grow as a proportion of all utilities (0.02% in 2016 and 2020)
- The numbers and percentages of light and rigid trucks which were EV/hybrid/other fuel types were similar and changed little from 2016 to 2020 (0.06% in 2016, to 0.06% for light rigid and 0.08% for heavy rigid in 2020)

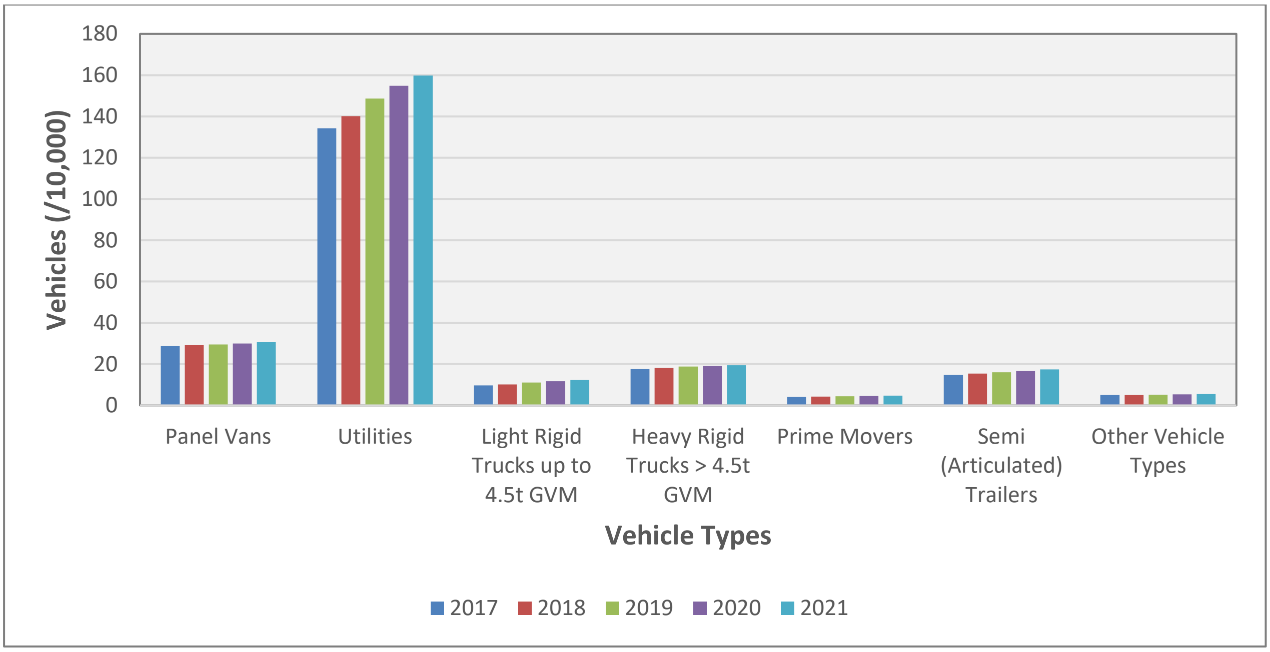

Figure 4.1. Annual vehicle counts (in millions) in urban areas by vehicle types between 2017 and 2021 [Other vehicle types = Tow Trucks + Trucks with Machinery Mounted + Other Non-Freight Carrying Trucks + Self-Propelled Plant and Equipment]

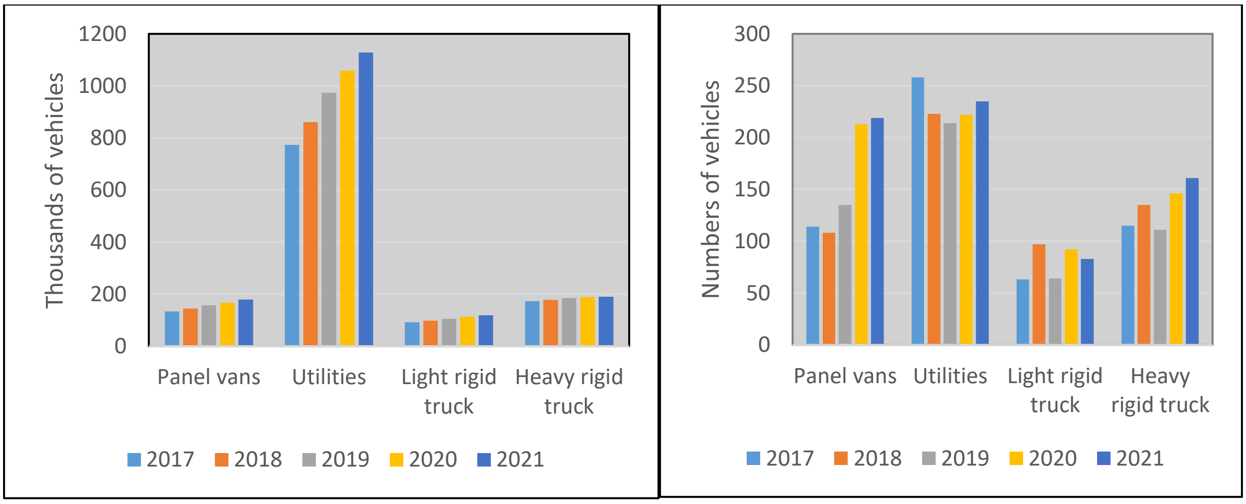

Figure 4.2. Thousands of diesel vehicles (left panel) and numbers of EV, hybrid and "other fuel type" (right panel) registered in urban areas.

4.2 DISTANCES TRAVELLED

While the number of UF and CS vehicles registered provides an indicator of trends, the distance travelled by these vehicles gives a clearer picture of trends in vehicle movements. The total distance travelled by light commercial vehicles (panel vans and utilities), rigid trucks and articulated trucks in capital cities was extracted from the 2016, 2018 and 2020 Surveys of Motor Vehicle Usage. In each year, three-quarters of the travel in capital cities by these vehicles involved light commercial vehicles (although about 40% of this was private and commuting use), with just under 20% by rigid trucks and about 5% by articulated trucks. Figure 4.3 shows that the distance travelled in capital cities increased from 2016 to 2020 (with most of the increase from 2016 to 2018) for all vehicle categories except articulated trucks up to 30 tonnes GCM. The relative amount of travel by vehicle categories remained similar across this period.

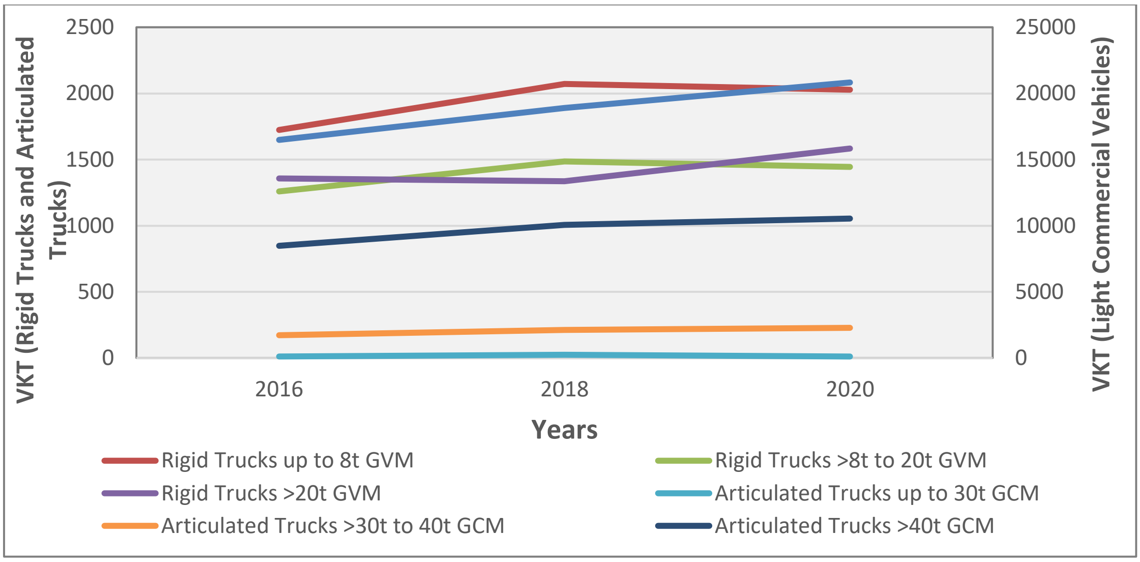

Figure 4.3. Total vehicle kilometres travelled by Light Commercial Vehicles, Rigid Trucks, and Articulated Trucks by GVM/GCM (for major journey type = In the Capital city)

4.3 VEHICLE OPERATING COSTS

Stakeholders identified the total of purchase and operating costs over a period of years would continue to be the most important influence in decisions to purchase new trucks in the future. In addition, decisions to purchase electric trucks were strongly influenced by the extent to which their reduced operating costs could offset initial purchase costs. Therefore, vehicle operating costs strongly influence shifts in urban freight and commercial services. The relevant assumptions, methods, and mathematical details of generating cost components are presented in the supplementary document.

Vehicle operating cost components were categorised into two groups:

(a) Invariant or fixed costs: The annual values of these components do not depend on whether or how often the vehicle has been used for any purpose (e.g., registration and vehicle capital costs).

(b) Variable costs: These costs are determined by the annual usage of the vehicle (e.g., kilometre travelled) as well as by other factors such as fuel unit prices and traffic conditions (e.g., annual fuel costs, and routine maintenance and service costs).

Some components such as labour may be either invariant or variable during a financial year, depending on the contract. Figure 4. presents a summary of the components and their underlying contributing factors.

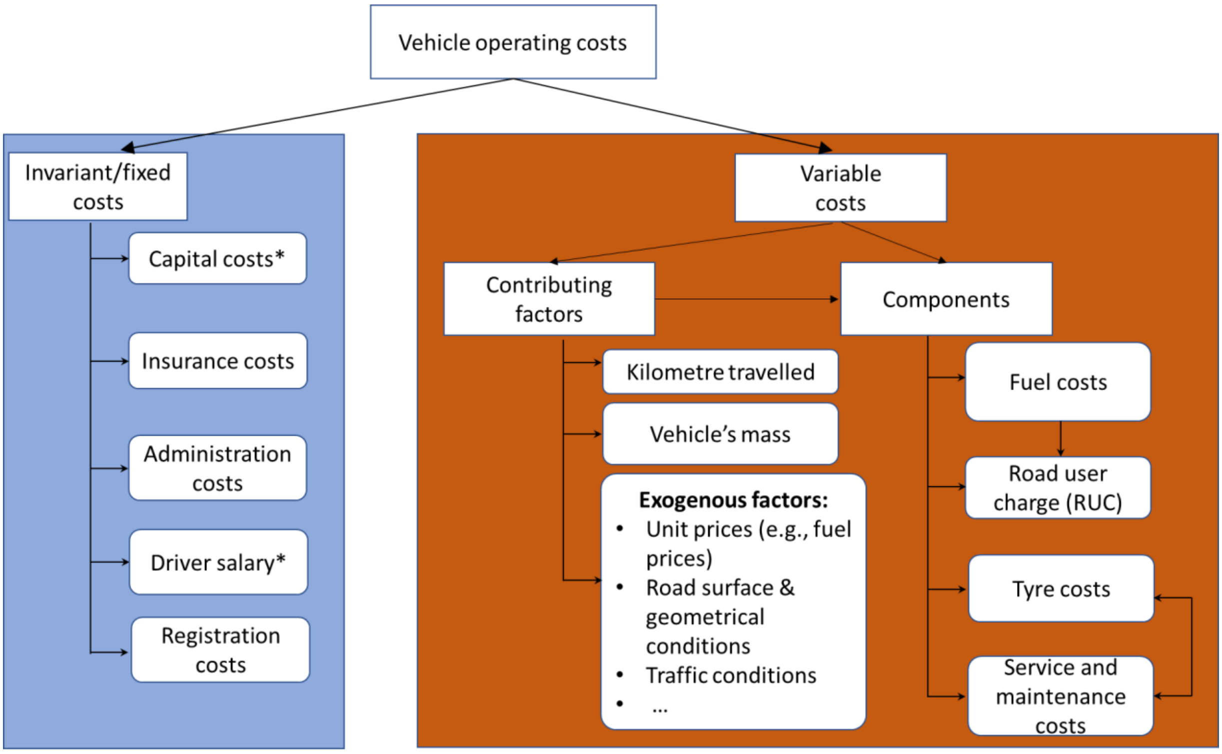

Figure 4.4. Summary of all the components together with their underlying contributing factors.* These costs can be regarded as variable in certain circumstances.

Two different approaches to estimating vehicle operating costs were developed. Approach A used average costs (which are reported in Section 4.3.1), while Approach B used per capita values instead and led to higher estimates each cost component, being more than double for some large vehicles. For these vehicle types, the ratio between total kilometres travelled by all vehicles and the total vehicle population could be smaller than the expected km travelled for active vehicles if a significant proportion of the vehicles recorded in the Survey of Motor Vehicle Use (SMVU) dataset were less active. We note that the per capita value might be more suitable for urban freight analysis from the policymaking perspective, whereas the average values might be more relevant for decision-making purposes by individuals and companies.

4.3.1 Trend analysis for different cost components

The overall trends in operating costs were estimated for some common vehicle types: light commercial vehicles under 4.5t, light rigid trucks under 4.5t, short combination trucks with GCM ≤ 42.5t, prime mover – short combination under 24t GCM and B-double multi-combination vehicles with GCM less than 62.5t. Figure 4.5 shows that some costs components have been relatively invariant while others are steadily growing. In some cases, such as the registration costs, this observation could be explained by the underlying assumptions behind the PayGo model, and that these charges are fixed expenses, and subject to marginal changes over the years until the regulations are revised. In some other cases, such as labour and office costs, the steady growth from year 2016 to 2021 is due to the underlying assumptions adopted in our approach, i.e., back-calculating such values from the year 2021 for which the information was available. However, fuel prices and fuel consumption have fluctuated in the SMVU dataset.

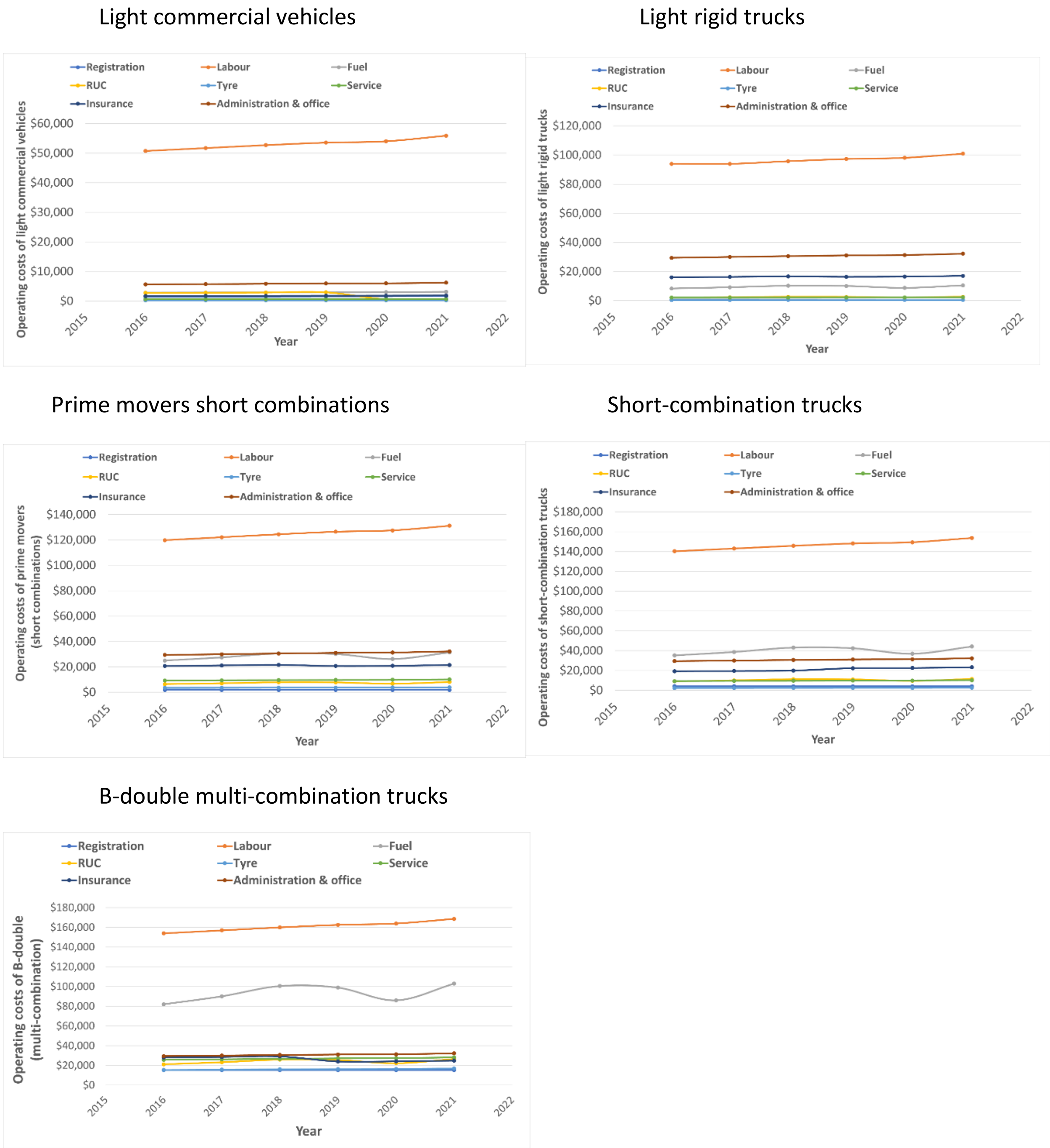

Figure 4.5 Trends in operating costs for some vehicle types between 2016 and 2021

Chapter 5: FINDINGS FROM MODELLING

Regression models were developed to identify how different explanatory variables are related to the numbers of vehicles in each postal area 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 were chosen based on the findings of the stakeholder consultations and earlier studies and represented land use, built environment, socio-economic factors and transport infrastructure (see list in Appendix C, Table C1).

Trends over time and possible effects of COVID-19 (in Motor Vehicle Census year 2021) were examined for urban areas with postcode area as the spatial unit of analysis. Elasticity estimates for the models will be developed as part of the next stage of the project. The findings presented here focus on the direction, rather than the magnitude, of the effects of factors found to be statistically significant.

Distance travelled data was not available by vehicle type at the postcode level and therefore could not be directly modelled. Instead, the implications for changes in vehicle movements are discussed in relation to the models where relevant.

5.1 MODELS OF NUMBER OF REGISTERED VEHICLES

A linear regression framework was used with logarithmic transformations of the dependent variable (number of registered vehicles per postal area) (see Rodríguez, 2016 for details). Separate models were developed for all vehicles regardless of age and vehicles not greater than five years old to examine whether the factors influencing vehicle purchase have changed in recent years (as suggested by the stakeholders consulted). Tables C2 and C3 in Appendix C present the estimation results of the models. The findings are summarised below.

The total number of UF and CS vehicles increased from 2016 to 2020 with no significant effect of the COVID-19 period and decreased as the average price of fuel (petrol and diesel) increased. This is consistent with the increase in total distance travelled shown in Figure 4.2 for all vehicle categories except articulated trucks under 30 tonnes GCM.

There were **more** UF and CS vehicles in postcodes

- in QLD, Vic and WA (and NSW for the newer vehicles only) than in SA and the ACT
- where incomes were higher
- where larger proportions of the total area were commercial or industrial areas (and covered areas, but not for the newer vehicles)
- where there were more kilometres of key freight rail and road routes

- with more train stations, petrol stations and electric vehicle charging stations
- closer to the CBD
- with more mining sites within 100kms of their boundaries

There were **fewer** UF and CS vehicles in postcodes:

- where larger proportions of total area were agricultural were (for the newer vehicles only)
- where larger proportions of the road network were highways and motorways
- further from airports.

5.2 MODELS OF NUMBER OF VEHICLES BY VEHICLE TYPE

Multinomial logit fractional split models were developed to identify the factors influencing the mix of UF and CS vehicle types. Separate models were developed for all vehicles (regardless of age) and vehicles not greater than five years old. Tables C4 and C5 of Appendix C present the estimation results for the models. The findings are summarised below.

The previous model showed an increase in the total UF and CS fleet but there was no significant change in the vehicle mix for the fleet as a whole over from 2016 to 2020 except for an increase in the proportion of light rigid trucks among the newer vehicles.

The UF and CS vehicle mix differed among jurisdictions and the mix was somewhat different for the newer vehicles for some vehicle types:

- More of the UF and CS vehicles were light commercial vehicles in QLD than in other jurisdictions.
- Light rigid trucks comprised less of the newer vehicle fleet in Vic than in some other jurisdictions but more of the total fleet, suggesting a recent move away from this type of vehicle in Vic.
- Heavy rigid trucks, prime movers and semi-articulated trailers made up relatively more of the fleet in Victoria than in some other jurisdictions.
- Semi-articulated trailers made up more of the fleet in SA than some other jurisdictions for the fleet as a whole, but less of the new fleet compared to other jurisdictions.

The proportions of all types of UF and CS vehicles (except light commercial vehicles) were **higher** in postcodes with larger proportions of total area that were industrial. The proportions of light rigid trucks were **higher** in more residential postcodes but these postcodes had **lower** proportions of heavy rigid trucks, prime movers, semi-articulated trailers and other vehicle classes.

The proportions of light commercial vehicles were **lower** in postcodes with more kms of key rail and freight routes and greater proportion of highways and motorways. In contrast, light and heavy rigid trucks, and prime movers comprised a **lower** proportion of UF and CS vehicles in postcodes that were more residential.

Postcodes that were further from airports had **larger** proportions of light commercial vehicles. There were also relatively **more** light commercial vehicles in postcodes closer to CBDs (for the newer vehicles only).

The proportions of UF and CS vehicles that were prime movers, semi-articulated trailers and other vehicles were **lower** in postcodes that were further from seaports.

For vehicles of all ages, **more** of the UF and CS vehicles were heavy rigid trucks in postcodes with more EV charging stations but this was not found for the newer vehicles.

For the newer vehicles, there were relatively **fewer** semi articulated trailers and other vehicle classes in postcodes with more mining sites with 100kms of their boundaries.

5.3 MODEL OF NUMBER OF VEHICLES BY VEHICLE MASS

Vehicle mass has an important influence on many outcomes such as road wear, fuel consumption, productivity and safety. An ordered logit fractional split framework was used to estimate the model with 'fraction of numbers of vehicles by GVM categories' as the dependent variable. Six categories of vehicle mass were included: 0-4.5t, >4.5-8t, >8-12t, >12-20t, >20-28t and >28t. Complexities in data access prevented the development of a separate model for vehicles not greater than five years old. Table C6 in Appendix C presents the estimation results for the model.

Given that vehicle mass is associated with vehicle type, it was expected that the factors influencing trends in the two characteristics might be similar.

The proportion of vehicles of higher GVMs did not differ significantly from 2016 to 2020 and there was no significant effect of COVID-19. Compared to NSW and the ACT, the proportions of vehicles of higher GVM were lower in SA and QLD and higher in Victoria.

Higher GVM was associated with more commercial, service and industrial areas in the postal area and less residential area. GVM decreased with distance from an airport and distance from the CBD but increased with the number of EV fast charging points in the postal area.

Lower GVMs were associated with higher-income and more densely populated postal areas. Higher GVMs were found in postal areas with more kilometres of key rail and road freight routes. Conversely, lower GVMs were associated with a greater proportion of local roads within the road network.

5.4 MODEL OF NUMBER OF VEHICLES BY FUEL TYPE

Multinomial logit fractional split models were developed to identify the factors influencing the mix of UF and CS vehicles by fuel types. Complexities in data access prevented the development of a separate model for vehicles not greater than five years old. Table C7 in Appendix C presents the estimation results for the model. The findings are summarised below.

The model was estimated combining all UF and CS vehicle categories, of which the majority are light commercial vehicles (panel vans and utilities). This vehicle type contains many petrol-engined vehicles and therefore many of the model results relate to the proportion of UF and CS vehicles that are petrol-engined.

The model is based on UF and CS vehicles of all ages, of which less than 1% are **EV/hybrid/other.** Therefore, there were relatively few significant findings regarding factors influencing the uptake of EV/hybrid/other vehicles. However, the model showed that, compared to WA and the ACT, the proportions were of this fuel type were lower in NSW, QLD, SA and higher in Vic. The split was also higher in postcodes with more commercial and residential areas and closer to airports.

The proportion of UF and CS vehicles that were EV/hybrid/other **did not change** to a statistically significant degree from 2016 to 2020 or as a function of the number of fast electric charging points in a postcode.

Interestingly, the average of petrol and diesel price did not significantly influence the mix of fuel types.

Chapter 6: CONCLUSIONS

The overarching aim of the Urban Freight Shifts (UFS) project is 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 project also created an integrated geospatial data tool by integrating all vehicle registration data and explanatory variables. The current report presents the initial results from the stakeholder consultations and the quantitative market analyses of UF and CS vehicle trends.

The key findings from the stakeholder consultations and the quantitative analyses are integrated and summarised in Table 6.1. In general, the findings from the two sources were consistent. The quantitative analyses based on newer vehicles appeared to be somewhat more aligned to the stakeholder comments. There were, however, some stakeholder comments which were not able to be tested or were not supported by the quantitative findings.

The largest shift in UF and CS vehicles was the move from petrol- (down by approximately 400,00 or 30%) to diesel-engined (up by approximately 100,000 or 19%) light commercial vehicles between 2017 and 2021. While three-quarters of the distance travelled by UF and CS vehicles in capital cities involves light commercial vehicles, it is important to note that about 40% of travel is for private and commuting purposes. Thus, only part of this large shift may actually be related to their use in UF and CS.

The stakeholder comments and the quantitative analyses both underlined the diversity of UF and CS vehicle fleets, with different mixes of vehicle types among jurisdictions and different trends for different vehicle types.

6.1 FUTURE TASKS

The stakeholder consultations and market trends analyses have identified the explanatory variables contributing towards current UF and CS vehicle trends. These estimates generated for UF and CS vehicle trends have multiple uses in elucidating trends and issues for policymakers and for urban freight analytical techniques, freight modelling improvements, methods of innovative freight and commercial service data collection and data sharing.

In the next phase of the project, the regression models will serve as the ‘base case’ scenario in developing the forecasting tool and in evaluating the transitions scenarios of UF and CS vehicle trends. The outcomes from the regression models will be used for developing road crash models in estimating the effects of UF and CS vehicle exposure on safety for different road user groups (vulnerable road user, heavy vehicles (based on the availability of information to the Project Team).

Table 6.1. Comparisons of key findings from stakeholder consultations and quantitative analyses

STAKEHOLDER CONSULTATIONS	QUANTITATIVE ANALYSES (EXPLORATORY ANALYSES AND REGRESSION MODELS)
Freight volumes had shown an increase over the last 10 years *(note: vehicle numbers could be a surrogate)*	▪ Total number of UF and CS vehicles increased from 2017 to 2021 as did the numbers of vehicles 5 years old or newer.
Volumes of freight were largely influenced by economic factors, with volumes increasing when the economy was strong and as a result of population growth (and a longer term move from rural to urban areas).	▪ Total vehicle numbers were not significantly associated with Gross State Product. ▪ Proportions of the population with medium-high and high-income were associated with more UF and CS vehicle registrations.
Freight associated with primary industries (mainly mining and agricultural exports) had increased and freight associated with local manufacturing had shrunk.	▪ There were more UF and CS vehicles in postal areas within 100kms of mining sites and in more industrial areas. ▪ However, total numbers of UF and CS vehicles were lower in more agricultural postcodes. This may just reflect lower population density and industrial/commercial activity in these areas.
International container transport is very much an urban freight task because most imported containers and many exported containers are transported by road less than 60 kms between the port and their origin or destination.	▪ The proportions of prime movers, semi-articulated trailers and other vehicle classes were greater in postal areas closer to a seaport.
Ports remained important destinations for large volume loads, and consequently the largest vehicles being used for urban road freight. There had been an increase in larger, more efficient vehicles being used for deliveries of large quantities to ports.	▪ Distance to a seaport was not a significant factor in the vehicle mass model.
Growth in small payload, urban delivery, particularly of hot foods and groceries to customers' homes was noted *(note: commercial area could be a surrogate for the origin of these activities)* Fulfilment centres for online shopping were located in industrial areas of major cities and were laid out similarly to a store, with a footprint of 7-10,000 square metres.	▪ Light rigid trucks were the only vehicle type with a significantly increasing proportion and this was only for vehicles not greater than 5 years old. ▪ Relatively more light commercial vehicles in postcodes close to CBDs among the newer vehicles only. ▪ The proportion of UF and CS vehicles that were light rigids was greater in more residential postcodes. ▪ Areas with greater commercial land area density had more UF and CS vehicles. ▪ Vehicle mass was lower in areas with greater residential density.
An industry organisation underlined the fragmented nature of the freight transport industry in Australia and commented that different trends could be experienced by different parts of the industry.	▪ Different jurisdictions showed different patterns in the numbers and proportions of UF and CS vehicles.

Origin and destination observed no real changes in the last 10 years. However, many participants noted that distribution centres had moved further from the centres of cities.	▪ Total numbers of UF and CS vehicles were higher in the postal areas farther away from CBD but only for the newer vehicles.
Urban freight originating from airports is small but increasing part of the urban freight task, not just at major airports but at new players such as Wellcamp and Moorabbin.	▪ Total numbers of UF and CS vehicles were higher in areas closer to airports but proportions which were light commercial vehicles were lower.
An increase in the largest heavy vehicles was noted. On the other hand, more growth in small heavy vehicles (4.5-9 tonnes) and light commercial vehicles (less than 4.5 tonnes) was discussed. The trend for large, combination heavy vehicles to have become larger and heavier in the last 10 years and an increase in the size of ships had contributed to less frequent but larger drops from ships.	▪ No significant increase in GVM occurred over the period. ▪ There were no significant increases in the proportions of the heavy vehicle classes over time but there was a significant increase in the proportion of light rigid trucks (among the newer vehicles only).
There had been very little take-up of electric freight vehicles	▪ Electric/hybrid/other vehicles comprised less than 1% of all UF and CS vehicles in 2021 and modelling found was no significant in the proportion of all UF and CS vehicles of this fuel type over time. ▪ Among 2.33 million UF and CS vehicles registered in 2021, only 1,440 vehicles were EV/hybrid/other and a large majority (1,235) of these were self-propelled plant and equipment vehicles.

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APPENDIX A: STAKEHOLDER SURVEY QUESTIONNAIRE:

STAKEHOLDER PERCEPTIONS OF SHIFTS IN URBAN FREIGHT

Q1. Which of the following best describes the type of organisation you work for?

1. Transport or logistics company that operates only heavy vehicles (>4.5 tonnes)
2. Manufacturer or distributor that contracts transport companies for delivery
3. Retailer
4. Federal government
5. State government
6. Local government
7. Industry organisation
8. University
9. Vehicle manufacturer
10. Involved in e-commerce
11. Microfreight company (e.g., food delivery, cargo bikes, drones)
12. None of the above

Q2. In which state or territory is your organisation based?

(Drop-down menu)

CHANGES IN THE LAST 10 YEARS

We are interested in your views on how urban freight transport has changed during the last 10 years. While we acknowledge that COVID-19 has deeply affected the industry, our focus here is on other types of changes.

Q3a. From your perspective, what changes have occurred in the TYPES of freight transported in and through urban areas? (please select all that apply)

1. No real changes in types
2. Shift from bulk to non-bulk
3. Shift from non-bulk to bulk
4. Other (please specify)……..

If response=1, proceed to Q4a.

Q3b. What do you think has caused these changes? Please describe.

Q3c. What have you done in response to these changes? Please describe.

Q4a. What changes have occurred in the VOLUMES of freight transported in and through urban areas? (please select all that apply)

1. No real changes in volumes
2. Increased
3. Decreased
4. Other (please specify)….

If response=1, proceed to Q5a.

Q4b. What do you think has caused these changes? Please describe.

Q4c. What have you done in response to these changes? Please describe.

Q5a. What changes have occurred in the ORIGINS of freight transported in and through urban areas? (please select all that apply)

1. No real changes in the origins
2. A larger proportion originating within urban areas
3. A smaller proportion originating within urban areas
4. A larger proportion from large distribution centres on the edge of urban areas
5. A smaller proportion from large distribution centres on the edge of urban areas
6. Other (please specify)………

If response=1, proceed to Q6a.

Q5b. What do you think has caused these changes? Please describe.

Q5c. What have you done in response to these changes? Please describe.

Q6a. What changes have occurred in the DESTINATIONS of freight transported in and through urban areas? (please select all that apply)

1. No real changes in the destinations
2. A larger proportion of destinations within urban areas
3. A smaller proportion of destinations outside urban areas
4. A larger proportion transported to large distribution centres on the edge of urban areas
5. A smaller proportion transported to large distribution centres on the edge of urban areas
6. Other (please specify)………

If response=1, proceed to Q7a.

Q6b. What do you think has caused these changes? Please describe.

Q6c. What have you done in response to these changes? Please describe.

Q7a. What changes have occurred in the TYPES OF VEHICLES USED for freight transported in and through urban areas? (please select all that apply)

1. No real changes in the types of vehicles
2. Relatively more smaller heavy vehicles (e.g., 4.5-9 tonnes)
3. Relatively more use of light commercial vehicles (less than 4.5 tonnes)
4. Relatively more larger heavy vehicles (e.g., shift from semi-trailers to B-doubles)
5. More electric trucks
6. Other (please specify)………

If response=1, proceed to Q8a.

Q7b. What do you think has caused these changes? Please describe.

Q7c. What have you done in response to these changes? Please describe.

Q8a. What changes have occurred in the URBAN ROAD SYSTEM that have affected freight transport in and through urban areas? (please select all that apply)

1. No real changes in the urban road system
2. Increases in congestion increasing delivery times
3. New toll roads or tunnels reducing delivery times
4. Introduction of prohibitions on trucks using particular roads (or at particular times)
5. Removal of prohibitions on trucks using particular roads (or at particular times)
6. Reductions in parking availability
7. Other (please specify)………

If response=1, proceed to Q9a.

Q8b. What do you think has caused these changes? Please describe.

Q8c. What have you done in response to these changes? Please describe.

Q9a. What changes have occurred in the REGULATIONS that have affected freight transport in and through urban areas? (please select all that apply)

1. No real changes in the regulations
2. Reductions in speed limits have increased delivery times
3. Increases in vehicle registration costs
4. Increases in driver-related costs
5. Strengthening of environmental controls (e.g., in relation to diesel)
6. Strengthening of health and safety rules
7. Other (please specify)………

If response=1, proceed to Q10a.

Q9b. What do you think has caused these changes? Please describe.

Q9c. What have you done in response to these changes? Please describe.

Q10a. In the last 10 years, how important have purchase versus operating costs been in decisions to buy new trucks?

1. Equally important
2. Purchase cost has been more important
3. Operating cost has been more important
4. The total of purchase and operating costs over a period of years has been most important
5. Other (please specify)………

CHANGES IN THE NEXT 10 YEARS

Now we would like to ask you about what changes you think might happen to urban freight transport in **the next 10 years**. We know that no-one has a crystal ball but we would still like to know what you think.

Q11a. From your perspective, what changes do you expect to occur in the TYPES of freight transported in and through urban areas? (please select all that apply)

1. No real changes in types
2. Shift from bulk to non-bulk
3. Shift from non-bulk to bulk
4. Other (please specify)……..

If response=1, proceed to Q12a.

Q11b. What do you think will cause these changes? Please describe.

Q11c. What do you think your organisation will do in response to these changes? Please describe.

Q12a. What changes do you expect to occur in the VOLUMES of freight transported in and through urban areas? (please select all that apply)

1. No real changes in volumes
2. Increased
3. Decreased
4. Other (please specify)….

If response=1, proceed to Q13a.

Q12b. What do you think will cause these changes? Please describe.

Q12c. What do you think your organisation will do in response to these changes? Please describe.

Q13a. What changes do you expect to occur in the ORIGINS of freight transported in and through urban areas? (please select all that apply)

1. No real changes in the origins
2. A larger proportion originating within urban areas
3. A smaller proportion originating within urban areas
4. A larger proportion from large distribution centres on the edge of urban areas
5. A smaller proportion from large distribution centres on the edge of urban areas
6. Other (please specify)………

If response=1, proceed to Q14a.

Q13b. What do you think will cause these changes? Please describe.

Q13c. What do you think your organisation will do in response to these changes? Please describe.

Q14a. What changes do you expect to occur in the DESTINATIONS of freight transported in and through urban areas? (please select all that apply)

1. No real changes in the destinations
2. A larger proportion of destinations within urban areas
3. A smaller proportion of destinations outside urban areas
4. A larger proportion transported to large distribution centres on the edge of urban areas
5. A smaller proportion transported to large distribution centres on the edge of urban areas
6. Other (please specify)………

If response=1, proceed to Q15a.

Q14b. What do you think will cause these changes? Please describe.

Q14c. What do you think your organisation will do in response to these changes? Please describe.

Q15a. What changes do you expect to occur in the TYPES OF VEHICLES USED for freight transported in and through urban areas? (please select all that apply)

1. No real changes in the types of vehicles
2. Relatively more smaller heavy vehicles (e.g., 4.5-9 tonnes)
3. Relatively more use of light commercial vehicles (less than 4.5 tonnes)
4. Relatively more larger heavy vehicles (e.g., shift from semi-trailers to B-doubles)
5. More electric trucks
6. Other (please specify)………

If response=1, proceed to Q16a.

Q15b. What do you think will cause these changes? Please describe.

Q15c. What do you think your organisation will do in response to these changes? Please describe.

Q16a. What changes do you expect to occur in the URBAN ROAD SYSTEM that have affected freight transport in and through urban areas? (please select all that apply)

1. No real changes in the urban road system
2. Increases in congestion increasing delivery times
3. New toll roads or tunnels reducing delivery times
4. Introduction of prohibitions on trucks using particular roads (or at particular times)
5. Removal of prohibitions on trucks using particular roads (or at particular times)
6. Reductions in parking availability
7. Other (please specify)………

If response=1, proceed to Q17a.

Q16b. What do you think will cause these changes? Please describe.

Q16c. What do you think your organisation will do in response to these changes? Please describe.

Q17a. What changes do you expect to occur in the REGULATIONS that have affected freight transport in and through urban areas? (please select all that apply)

1. No real changes in the regulations
2. Reductions in speed limits have increased delivery times
3. Increases in vehicle registration costs
4. Increases in driver-related costs
5. Strengthening of environmental controls (e.g., in relation to diesel)
6. Strengthening of health and safety rules
7. Other (please specify)………

If response=1, proceed to Q18.

Q17b. What do you think will cause these changes? Please describe.

Q17c. What do you think your organisation will do in response to these changes? Please describe.

Q18. How important do you think that purchase versus operating costs will be in decisions to buy new trucks in the next 10 years?

1. Equally important
2. Purchase cost will be more important
3. Operating cost will be more important
4. The total of purchase and operating costs over a period of years will be most important
5. Other (please specify)………

Q19. What technological changes do you expect in NEW TRUCKS BEING PURCHASED for urban freight in the next 10 years? (please select all that apply)

1. Nothing major
2. Improvements in engine technology
3. Increased availability of in-vehicle monitoring systems
4. Improvements in crash prevention technologies
5. More hybrid or electric trucks
6. Introduction of hydrogen-powered trucks
7. Other (please specify)………

Q20. What role do you think that AUTONOMOUS (I.E., SELF-DRIVING) TRUCKS will play in urban freight in the next 10 years?

1. None
2. Controlled trials only
3. Some use on designated routes (e.g., on motorways or to ports or distribution centres)
4. Some use of remote-controlled trucks but not fully autonomous
5. Starting to become widespread by the end of the 10 years
6. Other (please specify)………

Q21. What role do you think that DRONES will play in the delivery of small items in the next 10 years?

1. None
2. Controlled trials only
3. In some areas of cities
4. Some use of remote-controlled drones but not fully autonomous
5. Starting to become widespread by the end of the 10 years
6. Other (please specify)………

Q22. What role do you think that SMALL ELECTRIC VEHICLES *(like cargo bikes and mini-trucks)* will play in urban freight in the next 10 years?

1. None
2. Controlled trials only
3. In some central areas of cities
4. Some use of remote-controlled drones but not fully autonomous
5. Starting to become widespread by the end of the 10 years
6. Widespread throughout urban areas
7. Other (please specify)………

Q23. What information sources or publications do you rely on to plan for the future? (please select all that apply)

1. Government strategies/discussion papers etc.
2. Reports by industry organisations
3. Consultants' reports
4. In-house research
5. Conference presentations
6. Other (please specify)……

APPENDIX B: LIST OF UF AND CS VEHICLES WITHIN PROJECT SCOPE

Table B1. Representative vehicles considered within the project scope, their specifications, and corresponding class with respect to the Australian vehicle classification standard (VT stands for vehicle type)

Category representative	Australian classification	Descriptions	Trailer	GCM/GVM range
VT-1	2	Light commercials & Other light vehicles	no trailer	<4.5
VT-2	3	Light rigid trucks	no trailer	<4.5
VT-3	3	Rigid Truck type 1	no trailer	4.5 < GVM ≤ 7.0 t
VT-4	3	Rigid Truck type 1	no trailer	7.0 < GVM ≤ 12.0 t
VT-5	3	Rigid Truck type 2	no trailer	GVM > 12.0 t
VT-6	6	Short combination truck	with trailer	GCM ≤ 42.5 t
VT-7	4	Rigid Truck type 1	no trailer	4.5 < GVM ≤ 18.0 t
VT-8	4	Rigid Truck type 2	no trailer	GVM > 18.0 t
VT-9	9-10	Short combination truck	with trailer	GCM ≤ 42.5 t
VT-10	5	Rigid Truck type 1	no trailer	4.5 < GVM ≤ 25.0 t
VT-11	5	Rigid Truck type 2	no trailer	GVM > 25.0 t
VT-12	9-10	Short combination truck	with trailer	GCM ≤ 42.5 t
VT-13	?	Medium combination truck	with trailer	GCM > 42.5 t
VT-14	6	Prime mover-Short combination	3 axle rig	GCM<24
VT-15	7	Prime mover-Short combination	4 axle rig	GCM<31.5
VT-16	8	Prime mover-Short combination	5 axle rig	GCM<39
VT-17	8	Prime mover-Short combination	5 axle rig	GCM<39
VT-18	9	Prime mover-Short combination	6 axle rig	GCM<42.5
VT-19	9	Prime mover-Multi combination	< 9 axle rig	GCM<59
VT-20	9	B-double-multi-combination	≥ 9 axle rig	GCM<62.5
VT-21	10	B-double-multi-combination	2 trailers	GCM<59
VT-22	10	Prime mover-Multi combination	3 trailers	GCM<59
VT-23	10	Prime-mover- short combination	> 6 axle rig	GCM<62.5
VT-24	9-11	Special purpose & other	> 3 axle rig	GCM<62.5

Table B2. Definitions of vehicle types

TARGETED VEHICLE TYPES	DEFINITIONS
Panel Vans	Panel vans are light commercial motorised vehicles constructed to carry goods or specialised equipment that are less than or equal to 3.5 tonnes gross vehicle mass.
Utilities	Same as panel vans.
Light Rigid Trucks up to 4.5t GVM	Motor vehicles of GVM greater than 3.5 tonnes, constructed with a load carrying area. This includes trucks with a tow bar or fitted to take a draw bar or other non-articulated coupling on the rear of the vehicle. OR Rigid trucks of GVM greater than 3.5 tonnes and less than or equal to 4.5 tonnes
Heavy Rigid Trucks > 4.5t GVM	Rigid trucks of GVM greater than 4.5 tonnes.
Prime Movers	A heavy motor vehicle designed to tow a semi-trailer.
Semi (Articulated) Trailers	Motor vehicles constructed primarily for load carrying, consisting of a prime mover having no significant load carrying area, but with a turntable device which can be linked to one or more trailers.
Self-Propelled Plant and Equipment	The self-propelled machine is a special motorized wheeled or tracked machine with at least two axles.
Tow Trucks	A heavy motor vehicle that is – equipped with a crane, winch, ramp or other lifting device; and – used or intended to be used for the towing of motor vehicles; OR A heavy motor vehicle to which is attached, temporarily or otherwise, a trailer or device that is – equipped with a crane, winch, ramp or other lifting device; and – used or intended to be used for the towing of motor vehicles.
Trucks with Machinery Mounted	Trucks having fixed machinery such as an air compressor, concrete mixer, or drilling rig, etc.
Other Non-Freight Carrying Trucks	Specialist motor vehicles or motor vehicles fitted with special purpose equipment and having little or no goods carrying capacity.

Table B3. Numbers of types of vehicles registered 2017-2021

Vehicle types	Numbers of vehicles (/10,000)				
	Year				
	2017	2018	2019	2020	2021
1. Panel Vans	28.79	29.17	29.56	29.96	30.61
2. Utilities	134.26	140.12	148.73	154.80	159.87
3. Light Rigid Trucks up to 4.5t GVM	9.75	10.24	11.05	11.72	12.34
4. Heavy Rigid Trucks > 4.5t GVM	17.66	18.19	18.87	19.21	19.40
5. Prime Movers	4.10	4.27	4.45	4.54	4.67
6. Semi (Articulated) Trailers	14.79	15.41	15.99	16.74	17.39
7. Trailed Machinery	2.38	2.44	2.75	2.75	2.81
8. Trucks with Machinery Mounted	0.38	0.38	0.39	0.40	0.40
9. Other Non Freight Carrying Trucks	0.07	0.08	0.08	0.09	0.09
10. Self-Propelled Plant and Equipment	4.36	4.39	4.51	4.60	4.68
Total	**214.39**	**224.49**	**233.88**	**242.34**	**249.73**

Table B4. Number of vehicles by vehicle type and fuel type between 2017 and 2021

Vehicle Types	Fuel Types	Vehicle Counts				
		Year				
		2017	2018	2019	2020	2021
Light Commercial Vehicle	Diesel	907267	1006268	1130435	1225479	1308062
	Petrol	655424	625120	595017	570562	549231
	Dual fuel/LPG/other gases	67452	61216	56512	50229	45828
	EV/Hybrid/Other	372	331	349	435	454
Light Rigid Trucks up to 4.5t GVM	Diesel	92462	97738	105963	112684	118792
	Petrol	4071	3766	3589	3663	3741
	Dual fuel/LPG/other gases	865	779	790	663	632
	EV/Hybrid/Other	63	97	64	92	83
Heavy Rigid Trucks > 4.5t GVM	Diesel	172829	178288	185238	188570	190757
	Petrol	3123	2910	2745	2701	2402
	Dual fuel/LPG/other gases	515	553	455	422	408
	EV/Hybrid/Other	115	135	111	146	161
Prime Movers	Diesel	40600	42337	44158	45098	46407
	Petrol	321	330	291	252	233
	Dual fuel/LPG/other gases	48	57	48	36	42
	EV/Hybrid/Other	21	9	3	3	6
Other Vehicle Types	Diesel	39675	40713	41875	42848	43588
	Petrol	4698	4076	4442	4673	4760
	Dual fuel/LPG/other gases	4851	4862	4808	4749	4812
	EV/Hybrid/Other	1125	1232	1269	1260	1271

APPENDIX C: EXPLANATORY VARIABLES AND MODEL RESULTS

Table C1. List of explanatory variables and the relevant data sources

Explanatory Variables	Definitions	Data Sources
Land use features		
Service areas	Land areas for commercial or public services	Department of Agriculture, Water and the Environment, Australian Government (open source) (Land use and managment 2020)
Commercial areas	Land areas for shops, markets, and financial services	
Industrial areas	Land use for factory, major industrial complex, and manufacturing and other industrial activities.	
Agricultural areas	Land use for farm and agriculture	
Rural residential areas	Land use for rural residential areas with or without agricultural lands	
Urban residential areas	Land use for urban residential areas	
Built environment features		
Petrol stations		Australian Government data source (data.gov.au 2016)
Liquid fuel depots		Geoscience Australia (open source) (Geoscience Australia 2016)
Liquid fuel refineries		
Airports		National Freight Data Hub (National Freight Data Hub 2014)
Seaports		
Proximity to Central Business District (CBD)		
Number of mine sites		Western Australia dataset (open source) (data WA 2018)
Terrain	Ground surface topography	ArcGIS REST Services Directory (open access) (services.ga.gov.au 2015)
Electric vehicle fast-charging stations		Open charge map (open source) (Open Charge map 2022)
Building footprint	Land occupied by buildings	Microsoft building footprint (Open source) (Trifunović and Singh 2020)
Type of dwellings		ABS Census (open source) (Australian Bureau of Statistics 2016a, 2021)
Socio-economic features		
Income		ABS Census (open source) (Australian Bureau of Statistics 2016a, 2021)
Population		
Employment		
Transport infrastructures		
Road length by functional class and posted speed limit		Open Street Map (open source) (OpenStreetMap 2022)
Rail length		National Freight Data Hub (National Freight Data Hub 2014)
Rail station		
Key freight road route		
Key freight rail route		
Intermodal terminal		

Table C2. Total number of UF and CS vehicles model results (linear regression model)

Variables	Definitions/functional form	Estimates	p-value
Constant	-	5.507	>0.000
Temporal variables			
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	0.042	0.007
COVID-19 period	Year 2021=1; 0 = Otherwise	0.035	0.625
Geographical boundary			
State/Territory (Base: NSW, SA, and ACT)			
QLD	QLD = 1; 0 = Otherwise	0.406	>0.000
VIC	VIC = 1; 0 = Otherwise	0.142	0.019
WA	WA = 1; 0 = Otherwise	0.631	0.000
Socio-economic variables			
Proportion of medium-high income population	Total medium-high income population in a postal area/Total population in a postal area	8.662	>0.000
Proportion of high income population	Total high income population in a postal area/Total population in a postal area	1.877	>0.000
Gross State Product	Gross State Product	0.028	0.097
Land use features			
Commercial area density	Total commercial area in a postal area/Total area of a postal area	0.623	0.022
Residential area density	Total residential (urban + rural) area in a postal area/Total area of a postal area	0.182	0.001
Industrial area density	Total industrial area in a postal area/Total area of a postal area	2.417	>0.000
Covered area	Total covered area in a postal area/Total area of a postal area	-1.021	>0.000
Transportation infrastructure			
Key freight rail routes	Key freight rail route in a postcode (km)	0.015	0.002
Key freight road routes	ln(Key freight road route in a postcode (km))	0.013	>0.000
Proportion of highways/motorways	Length of (highways/motorways) in a postal area/Total length of roadways in a postal area	-1.791	>0.000
Built environment features			
Train stations	Number of train stations in a postcode	0.061	>0.000
Electric vehicle charging stations	Number of fast charging points in a postcode	0.019	>0.000
Petrol stations	Number of petrol stations in a postcode	0.233	>0.000
Distance to CBD	ln(Euclidean distance between centroid of a postcode and nearest CBD (km))	0.139	>0.000
Distance to airport	Distance between a postal area's centroid to the airport zone's centroid (km)/10	-0.085	>0.000

Mining sites	Number of mining sites within 100 km from the boundary of a postcode/100	0.070	0.013
Cost attributes			
ln of averaged petrol and diesel price	ln ((annual average diesel + petrol price)/2)	-0.355	0.140

Table C3. Total number of UF and CS vehicles with age ≤5 years (linear regression model)

Variables	Definitions/functional forms	Estimates	p-value
Constant	-	4.265	<0.000
Temporal variables			
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	0.043	0.004
COVID-19 period	Year 2021=1; 0 = Otherwise	-0.004	0.959
Geographical boundary			
State/Territory (Base: SA and ACT)			
NSW	NSW = 1; 0 = Otherwise	0.135	0.017
QLD	QLD = 1; 0 = Otherwise	0.461	<0.000
VIC	VIC = 1; 0 = Otherwise	0.217	0.001
WA	WA = 1; 0 = Otherwise	0.345	<0.000
Socio-economic variables			
Proportion of medium-high income population	Total medium-high income population in a postal area/Total population in a postal area	7.323	<0.000
Proportion of high income population	Total high income population in a postal area/Total population in a postal area	2.120	<0.000
Gross State Product	Gross State Product	0.027	0.106
Land use features			
Commercial area density	Total commercial area in a postal area/Total area of a postal area	0.887	0.001
Industrial area density	Total industrial area in a postal area/Total area of a postal area	2.580	<0.000
Agricultural area density	Total agricultural area in a postal area/Total area of a postal area	-0.146	0.039
Transportation infrastructure			
Key freight rail routes	Key freight route - rail in a postcode (km)	0.012	0.014
Key freight road routes	ln(Key freight route - road in a postcode (km))	0.014	<0.000
Proportion of highways/motorways	Length of highways/motorways in a postal area/Total length of roadways in a postal area	-1.688	0.000
Built environment features			
Train stations	Number of train stations in a postcode	0.066	<0.000
Electric vehicle charging stations	Number of fast charging points in a postcode	0.024	<0.000
Petrol stations	Number of petrol stations in a postcode	0.236	<0.000
Distance to CBD	ln(Euclidean distance between centroid of a postcode and nearest CBD (km))	0.129	<0.000
Distance to airport	(Euclidean distance between centroid of a postcode and nearest airport (km))/100	-0.077	<0.000

Mining sites	Number of mining sites within 100 km from the boundary of a postcode - divided by 100	0.084	0.003
Cost attributes			
Averaged petrol and diesel price	ln ((annual average diesel + petrol price)/2)	-0.313	0.183

Table C4. Proportion of UF and CS vehicles by vehicle class model results (multinomial logit fractional split model)

Variables	Definitions/functional forms	Light Commercial Vehicles		Light Rigid Trucks		Heavy Rigid Trucks		Prime Movers		Semi Articulated Trailers		Other Vehicle Classes	
		Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value
Constant	-	--	--	-2.872	<0.000	-2.202	<0.000	-3.349	<0.000	-2.170	<0.000	-3.113	<0.000
Temporal variables													
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	--	--	0.016	0.190	-0.017	0.096	-0.017	0.096	-0.017	0.096	-0.017	0.096
COVID-19 period	Year 2021=1; 0 = Otherwise	--	--	0.007	0.859	-0.014	0.712	-0.014	0.712	0.021	0.615	0.021	0.615
Geographic boundary													
State/Territory (Base: WA, and ACT)													
QLD	QLD = 1; 0 = Otherwise	0.183	<0.000	--	--	--	--	--	--	--	--	--	--
SA	SA = 1; 0 = Otherwise	--	--	-0.640	<0.000	--	--	--	--	0.101	0.008	0.101	0.008
VIC	VIC = 1; 0 = Otherwise	--	--	0.072	0.003	0.296	<0.000	0.296	<0.000	0.072	0.003	0.296	<0.000
Land use features													
Residential area density	Total residential (urban + rural) area in a postal area/Total area of a postal area	--	--	0.204	<0.000	-0.371	<0.000	-0.371	<0.000	-0.371	<0.000	-0.371	<0.000
Commercial area density	Total commercial area in a postal area/Total area of a postal area	--	--	0.470	<0.000	0.470	<0.000	--	--	--	--	--	--
Industrial area density	Total industrial area in a postal area/Total area of a postal area	--	--	1.413	<0.000	1.413	<0.000	1.413	<0.000	2.027	<0.000	1.413	<0.000
Transport infrastructures													
Key freight rail routes	Key freight rail route in a postcode (km)	-0.016	<0.000	--	--	--	--	--	--	--	--	--	--
Key freight road routes	ln(Key freight road route in a postcode (km))	-0.008	<0.000	--	--	--	--	--	--	--	--	--	--
Proportion of highways/motorways	Length of (highways/motorways) in a postal area/Total length of roadways in a postal area	-1.028	<0.000	--	--	--	--	--	--	--	--	--	--
Proportion of local roads	Length of local roads in a postal area/Total length of roadways in a postal area	--	--	-0.494	<0.000	-0.494	<0.000	-0.494	<0.000	--	--	1.129	<0.000
Built environment features													

Distance to seaport	(Euclidean distance between centroid of a postcode and nearest seaport (km))/100	--	--	--	--	--	--	-0.709	<0.000	-0.181	<0.000	-0.709	<0.000
Distance to airport	(Euclidean distance between centroid of a postcode and nearest airport (km))/100	0.109	<0.000	--	--	--	--	--	--	--	--	--	--
Electric vehicle charging stations	Number of fast charging points in a postcode	--	--	--	--	0.003	<0.000	--	--	--	--	--	--

Table C5. Proportion of UF and CS vehicles by vehicle class model results for vehicles with age ≤5 years (multinomial logit fractional split model)

Variables	Definitions/functional forms	Light Commercial Vehicles		Light Rigid Trucks		Heavy Rigid Trucks		Prime Movers		Semi Articulated Trailers		Other Vehicle Classes	
		Est.	p-value	Est.	p-value	Est.	p-value			Est.	p-value	Est.	p-value
Constant	-	--	--	-2.459	0.001	-2.107	0.003	-2.956	0.000	-1.665	0.019	-2.240	0.002
Temporal variables													
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	--	--	0.068	0.000	-0.011	0.348	-0.011	0.348	-0.011	0.348	-0.011	0.348
COVID-19 period	Year 2021=1; 0 = Otherwise	-0.044	0.246	--	--	--	--	--	--	--	--	--	--
Geographic boundary													
State/Territory (Base: WA, NSW, and ACT)													
QLD	QLD = 1; 0 = Otherwise	0.147	0.000	--	--	--	--	--	--	--	--	--	--
SA	SA = 1; 0 = Otherwise	--	--	-0.724	0.000	--	--	--	--	-0.724	0.000	--	--
VIC	VIC = 1; 0 = Otherwise	--	--	-0.185	0.000	0.079	0.012	0.079	0.012	0.079	0.012	--	--
Socio-economic variables													
Proportion of medium-high income population	Total medium-high income population in a postal area/Total population in a postal area	--	--	--	--	--	--	1.829	0.002	1.829	0.002	--	--
Proportion of high income population	Total high income population in a postal area/Total population in a postal area	1.973	0.000	--	--	--	--	--	--	--	--	--	--
Land use features													
Residential area density	Total residential (urban + rural) area in a postal area/Total area of a postal area	--	--	0.389	0.000	-0.158	0.000	-0.158	0.000	-0.158	0.000	-0.158	0.000
Industrial area density	Total industrial area in a postal area/Total area of a postal area	--	--	1.264	0.000	1.264	0.000	1.264	0.000	1.661	0.000	1.264	0.000
Transport infrastructures													
Key freight routes - rail	Key freight route - rail in a postcode (km)	-0.015	0.000	--	--	--	--	--	--	--	--	--	--

Key freight routes - road	ln(Key freight route - road in a postcode (km))	-0.008	0.000	--	--	--	--	--	--	--	--	--	--
Proportion of highways/motorways	Length of (highways/motorways) in a postal area/Total length of roadways in a postal area	-0.873	0.000	--	--	--	--	--	--	--	--	--	--
Proportion of local roads	Length of local roads in a postal area/Total length of roadways in a postal area	--	--	-0.320	0.000	-0.320	0.000	-0.320	0.000	--	--	-0.888	0.007
Built environment features													
Distance to seaport	(Euclidean distance between centroid of a postcode and nearest seaport (km))/100	--	--	--	--	--	--	-0.926	0.000	-0.239	0.000	-0.926	0.000
Distance to airport	(Euclidean distance between centroid of a postcode and nearest airport (km))/100	0.071	0.000	--	--	--	--	--	--	--	--	--	--
Petrol stations	Number of petrol stations in a postcode	--	--	0.023	0.000	0.023	0.000	--	--	--	--	--	--
Distance to CBD	ln(Euclidean distance between centroid of a postcode and nearest CBD (km))	0.166	0.000	--	--	--	--	--	--	--	--	--	--
Mining sites	Number of mining sites within 100 km from the boundary of a postcode - divided by 100	--	--	--	--	--	--	--	--	-0.077	0.000	-0.077	0.000
Cost attributes													
Averaged petrol and diesel price	ln ((annual average diesel + petrol price)/2)	-0.048	0.739	--	--	--	--	--	--	--	--	--	--

Table C6. Proportion of UF and CS vehicles by vehicle mass results (ordered logit fractional split regression model)

Variables	Definitions/functional forms	Estimates	p-value
Temporal variables			
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	-0.002	0.864
COVID-19 period	Year 2021=1; 0 = Otherwise	0.024	0.453
Geographic boundary			
State/Territory (Base: NSW, and ACT)			
SA	SA = 1; 0 = Otherwise	-0.200	0.000
QLD	QLD = 1; 0 = Otherwise	-0.304	0.000
VIC	VIC = 1; 0 = Otherwise	0.156	0.000
WA	WA = 1; 0 = Otherwise	-0.076	0.082
Land use features			
Residential area density	Total residential (urban + rural) area in a postal area/Total postal area	-0.264	0.000
Commercial area density		0.782	0.000
Service area density	Total service area in a postal area/Total postal area	1.251	0.000
Industrial area density	Total industrial area in a postal area/Total postal area	0.794	0.000
Built environment features			
Mining sites	Number of mining sites within 100 km from the boundary of a postcode/100	-0.030	0.099
Airport distance	Distance between a postal area's centroid to the airport zone's centroid (km)/10	-0.082	0.000
Distance to CBD	ln(Euclidean distance between centroid of a postcode and nearest CBD (km))	-0.160	0.000
EV fast charging stations	Number of EV fast charging points in a postal area	0.004	0.002
Socioeconomic features			
Proportion of high-income population	Total high-income population in a postal area/Total population in a postal area	-2.315	0.000
Population density	Total population in a postal area/(Total area of a postcode - km^2 * 1000)	-0.095	0.000
Transport infrastructure			

Key freight routes - rail	Key freight route - rail in a postal area (km)	0.006	0.011
Key freight routes - road	Key freight route - road in a postal rea (km)	0.009	0.000
Proportion of local roads	Length of local roads in a postal area/Total length of roadways in a postal area	-0.530	0.000

Table C7. Proportion of UF and CS vehicles by fuel type model results (multinomial logit fractional split model)

Variables	Definitions/functional forms	Diesel		Petrol		Dual fuel/LPG/other gases		EV/Hybrid/Other	
		Est.	p-value	Est.	p-value	Est.	p-value	Est.	p-value
Constant	-	--	--	-0.246	0.471	-3.027	<0.000	-5.751	<0.000
Temporal variables									
Time elapsed	Time elapsed from 2017 (2017=0, 2018=1, 2019=2, 2020=3 and 2021=4)	--	--	-0.132	<0.000	-0.132	<0.000	--	--
COVID-19 period	Year 2021=1; 0 = Otherwise	--	--	0.069	<0.000	-0.054	0.020	-0.063	0.673
Geographic boundary									
State/Territory (Base: WA, and ACT)									
NSW	NSW = 1; 0 = Otherwise	--	--	0.116	<0.000	-0.305	<0.000	-0.669	<0.000
QLD	QLD = 1; 0 = Otherwise	--	--	--	--	-0.899	<0.000	-0.899	<0.000
SA	SA = 1; 0 = Otherwise	--	--	0.148	<0.000	-0.964	<0.000	-0.964	<0.000
VIC	VIC = 1; 0 = Otherwise	--	--	-0.146	<0.000	0.514	<0.000	0.514	<0.000
Socioeconomic features									
Proportion of high income population	Total high income population in a postal area/Total population in a postal area	0.320	<0.000	--	--	--	--	--	--
Land use features									
Commercial area density	Total commercial area in a postal area/Total area of a postal area	--	--	-0.614	<0.000	-0.614	<0.000	2.020	<0.000
Residential area density	Total residential (urban + rural) area in a postal area/Total area of a postal area	--	--	0.208	<0.000	0.208	<0.000	0.413	0.013
Industrial area density	Total industrial area in a postal area/Total area of a postal area	--	--	-0.655	<0.000	-0.655	<0.000	--	--
Transport infrastructure									
Key freight road routes	ln(Key freight road route in a postcode (km))	--	--	-0.004	<0.000	--	--	--	--
Proportion of highways/motorways	Length of (highways/motorways) in a postal area/Total length of roadways in a postal area	--	--	-0.533	<0.000	-0.533	<0.000	--	--
Train stations	Number of train stations in a postcode	--	--	--	--	--	--	-0.068	0.074

Built environment features									
Distance to CBD	ln(Euclidean distance between centroid of a postcode and nearest CBD (km))	--	--	--	--	0.138	<0.000	--	--
Distance to airport	(Euclidean distance between centroid of a postcode and nearest airport (km))/100	--	--	--	--	--	--	-0.450	<0.000
Mining sites	Number of mining sites within 100 km from the boundary of a postcode - divided by 100	--	--	-0.060	<0.000	-0.060	<0.000	--	--
Cost attributes									
ln of averaged petrol and diesel price	ln ((annual average diesel + petrol price)/2)	--	--	-0.032	0.652	-0.010	0.362	--	--