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Road

# Truck productivity: sources, trends and future prospects

Bureau of Infrastructure, Transport and Regional Economics

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# Foreword

The size of the Australian continent, geographically dispersed population base and importance of major commodities to Australia's economic output means that freight transport sector performance has a significant influence on national productivity and efficiency. Improvements in freight productivity and efficiency reduce the cost of moving freight, adding directly to national economic output.

The Australian freight task has quadrupled over the last four decades. This has coincided with significant improvements in freight sector productivity, most especially in road freight where physical freight vehicle productivity has increased more than doubled over the same period. With total freight projected to nearly double again over the next two decades, and most of the additional freight expected to be carried by road or rail, trends in future freight productivity will significantly influence the efficiency with which this additional freight is moved.

This report analyses historical trends in road freight productivity growth, identifies the major sources of productivity growth and explores the prospects for future productivity growth. The findings will be of major interest to transport policy makers and infrastructure managers.

The report was prepared by David Mitchell, with assistance from Jack McAuley and Pearl Louis. Andrew Hyles, Stuart Sargeant and Sally Todd, of the Department of Infrastructure and Transport, provided feedback on the draft report. BITRE also acknowledges early discussions with Terry Pennington, of the Truck Industry Council, which helped inform this work.

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March 2011

# At a glance

- Total domestic road freight has grown six-fold over the last four decades, from around 27 billion tonne kilometres in 1971 to over 180 billion tonne kilometres in 2007. (A tonne kilometre is one tonne of freight moved one kilometre.)
- Over that period the average productivity of road freight vehicles—that is, the freight carried per registered freight vehicle, including light commercial vehicles (LCVs)—has more than doubled. As a result, the 2007 road freight task required half as many vehicles as would have been required in the absence of productivity growth.
- Productivity growth of heavy freight vehicles—that is, rigid and articulated trucks—has been even more pronounced; increasing almost six-fold since 1971. Articulated trucks alone have contributed over 90 per cent of the increase in total road freight vehicle productivity.
- The principal factors contributing to increased heavy vehicle productivity include:
  - the introduction of and expanded network access for larger heavy vehicle combinations, particularly B-double articulated trucks
  - progressive increases in regulated heavy vehicle mass and dimension limits
  - strong growth in long-distance freight
  - cumulative long-term investment in major road infrastructure—particularly the realignment and duplication of parts of the intercapital national highway network.
- Modelling suggests that future heavy vehicle productivity growth is likely to be more muted. In particular:
  - In the absence of further heavy vehicle productivity enhancing regulatory reform, fleet-wide heavy vehicle average loads are likely to increase by less than 5 per cent between 2010 and 2030, which contrasts sharply with the 40 per cent growth in average loads over the past two decades.
  - Increased uptake of higher productivity vehicles available under Performance Based Standards (PBS), such as B-triples and AB-triples, is likely to have a relatively small impact on national heavy vehicle productivity since freight that can take advantage of these larger vehicles represents less than 20 per cent of total road freight. Nevertheless, these larger vehicle combinations offer important increases in heavy vehicle productivity and freight transport efficiency for transport operators, produces and consumers in rural and remote areas.
- With the Australian road freight task projected to nearly double between 2010 and 2030, slower future freight productivity growth implies significant increases in the number of heavy vehicles, and drivers, to meet the projected future freight task.

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# Executive summary

Freight transport plays a significant role in the Australian economy. Rail and sea transport are essential parts of Australia's major export commodity supply chains—coal and iron ore, for example, comprise over 75 per cent of all Australian rail freight. Coastal shipping carries significant volumes of bulk commodities for further processing and refining, and is the only mode of transport for most goods moved between Tasmania and the mainland. Road is the predominant mode of transport for urban, inter-urban and regional freight, and part of the supply chain for most imports.

Improvements in freight productivity reduces the cost of moving freight and contributes directly to increased national economic output. Freight productivity growth also benefits other transport system users, for example, by reducing the number of vehicles on road and rail networks, thereby reducing accident exposure risk for other road users, and reducing noxious and greenhouse emissions per unit of freight moved.

This report examines trends in Australian road freight productivity over the past four decades and the factors that have contributed to growth in freight vehicle productivity. The report also presents projections of potential future road freight productivity growth.

## Australian freight trends

The Australian domestic freight task has grown eight-fold over the past five decades, from around 62 billion tonne kilometres in 1961 to approximately 514 billion tonne kilometres in 2006–07. This is equivalent to average annual growth of approximately 4.7 per cent per annum, significantly faster than annual growth in GDP, which averaged 3.7 per cent per annum over the same period. Road transport accounted for 35 per cent of total freight tonne kilometres in 2007–08, rail 41 per cent and coastal shipping 24 per cent.

### *Trends in road freight activity*

Since 1971, Australia's road freight task has grown by approximately 5.4 per cent per annum, from 27.2 billion tonne kilometres to approximately 184.1 billion tonne kilometres in 2007 (ABS 2008), outstripping growth in both rail and domestic sea freight.

Over this period, increases in road freight vehicle size and capacity has enabled more freight to be carried by proportionately fewer trucks, and larger trucks have captured a larger share of the road freight task. The share of the road freight carried by articulated trucks has increased from around 55 per cent in 1971 to around 78 per cent in 2007. As a consequence, the average load carried by articulated trucks has more than doubled, from 9.7 tonnes per vehicle kilometre in 1971 to over 20.7 tonnes per vehicle kilometre in 2007, and the average distance travelled by articulated trucks has increased almost 90 per cent to over 90 000 kilometres per annum.

The impacts of these increases in heavy vehicle average loads and average utilisation have been profound. In the absence of any increase in heavy vehicle productivity between 1971 and 2007, more than twice as many articulated trucks (nearly 150 000 vehicles) would have been required to undertake the 2007 articulated truck freight task, than the 70 000 articulated trucks actually in registered use in that year.

## Role of productivity

Productivity measures the quantity of outputs per unit of input, either expressed in terms of value or physical quantity of output. For example, labour productivity measures the amount of output produced per employee or per hour worked. Total, or multi-factor, productivity growth measures the growth in productivity relative to all factors used in production.

Productivity growth is a crucial source of increasing living standards—enabling production of more output from fewer inputs—and adds directly to national economic output. At the industry or firm level, improvements in productivity reduce unit production costs, contributing to lower consumer prices and/or increased industry profitability.

The three most commons sources of productivity growth are:

- improvements in technology and/or processes of production
- increased organisational efficiency of firms and industries
- re-allocation of resources to more productive sectors.

This report focusses on improvements in freight vehicle productivity, generally measured as total tonne kilometres per vehicle. This measure encapsulates both changes in the average load carried by freight vehicles and the average intensity of freight vehicle use. Other measures of road freight vehicle productivity that could be considered include output per driver hour (direct labour input) or per unit of fuel used—a measure of the average fuel efficiency improvement in the road freight vehicle task.

Heavy vehicle productivity growth is not necessarily costless. Increased freight vehicle productivity, occasioned by increased use of larger and heavier trucks, may increase road wear causing accelerated deterioration of road infrastructure and necessitating earlier road maintenance and repairs. This report does not consider in detail the impact of increased freight vehicle productivity on road construction and maintenance costs.

### *Transport sector productivity growth*

Hire and reward transport and storage sector total factor productivity has generally grown faster than economy-wide total factor productivity over the past two decades. For example, between 1985–86 and 2007–08 transport and storage sector total factor productivity growth averaged 1.6 per cent per annum, whereas economy-wide market sector total factor productivity growth averaged 1.0 per cent per annum. (The hire and reward transport and storage sector includes both freight and passenger transport businesses—the latter include taxi operators and airlines, among others.)

Both labour and capital factor productivity growth in the transport and storage sector were above average economy-wide market sector productivity growth. Transport and storage sector labour productivity growth averaged 2.3 per cent per annum between 1985-86 and 2007–08, compared to 2.2 per cent per annum across the economy, and capital factor productivity growth in the transport and storage sector averaged 0.6 per cent per annum versus –0.4 per cent per annum across the economy.

# Road freight productivity growth

As already noted, the Australian road freight task grew more than six-fold between 1971 and 2007 with much of this growth due to above average growth in freight carried by articulated trucks. Articulated truck freight grew by an average of 6.4 per cent per annum over this period. By contrast, freight carried by rigid trucks grew by only 3.2 per cent per annum. As a consequence, the share of freight carried by articulated trucks has increased from 55 per cent in 1971 to 78 per cent in 2007, and the share of freight carried by rigid trucks has fallen from around 40 per cent in 1971 to around 18 per cent in 2007. Freight carried by light commercial vehicles (LCVs), which are responsible for less than 5 per cent of total road freight, also grew relatively strongly over this period, averaging growth of 5.3 per cent per annum.

The average load carried by articulated trucks—inclusive of unladen use (empty running)—has doubled from around 9.7 tonnes per vehicle kilometre in 1971 to over 20 tonnes per vehicle kilometre in 2007. The average distance travelled by articulated trucks also increased, by almost 90 per cent to over 90 000 kilometres per vehicle per annum in 2007. The combined effect of these two improvements has resulted in a 300 per cent increase in articulated truck average productivity since 1971.

The productivity of rigid trucks and LCVs has also increased—rigid truck productivity increased 170 per cent and LCV productivity doubled between 1971 and 2007, with the majority of the growth in productivity attributable to increases in vehicle average loads.

The combined impact of growth in rigid and articulated truck productivity has resulted in an almost six-fold increase in total *heavy vehicle*—that is, rigid and articulated trucks 4.5 tonnes and above—productivity growth since 1971.

As a result of both increased average vehicle productivity and growth in the share of freight carried by articulated trucks, almost 95 per cent of total freight vehicle productivity growth is attributable to articulated trucks.

# Sources of road freight productivity growth

Increasing use of larger heavy vehicle combinations, facilitated by regulated increases in network access for larger vehicles, and progressive increases in mass, dimension and speed limit restrictions for existing heavy vehicle combinations, as well as government-funded infrastructure improvements have all contributed to increased heavy vehicle productivity.

Approximately 80 per cent of the increase in fleet-wide heavy vehicle average loads appears to be attributable to the increased share of freight carried by larger heavy vehicle combinations, with the remaining 20 per cent explained by increases in vehicle mass and dimension limits.

## *Network access*

Heavy vehicle network access has expanded significantly since 1971, particularly for larger articulated truck combinations.

Use of tri-axle trailers became more widespread in the early 1970s, as operators took advantage of higher vehicle mass limits available with these trailers, facilitating the increased take-up of six-axle articulated truck combinations. Six-axle articulated trucks quickly became the predominant road freight vehicle combination in Australia.

B-doubles were first trialled in Australia in the early 1980s. Following safe and successful operation of these vehicles on limited networks, B-doubles were granted more general network access in the early 1990s. Since then, B-double network access has gradually expanded to include all intercapital routes and most major arterial roads in metropolitan areas.

Road trains have been used in remote areas in South Australia, Western Australia and Northern Territory since the 1920s. Road train access was expanded significantly in the 1990s to include rural and remote highways in New South Wales and Queensland.

## Vehicle mass and dimension limits

Heavy vehicle mass and dimension limits are controlled by State and Territory legislation principally to manage road assets and limit pavement deterioration, but also to ensure safe on-road heavy vehicle performance. Since 1971 there have been six major revisions to heavy vehicle mass and dimension limits. The cumulative impact of these revisions has resulted in articulated truck mass limit increases of between 15 and 28 per cent under General Mass Limits (GML) and 33 per cent incorporating Higher Mass Limits (HML). Over the same period, rigid truck mass limits have increased by between 15 and 24 per cent.

Regulated changes in heavy vehicle dimension (length) limits have increased the maximum allowable length of rigid trucks by 7 per cent since 1971 and that of articulated trucks by 25 per cent.

## Driving hour limits

Regulations governing heavy vehicle driving hours limit the number of hours a professional driver can work before taking a rest. Prior to the implementation of model national driving hour legislation in 1999, driving hour limits were set separately by each State and Territory. Maximum continuous driving time without a break varied between 5.0 and 5.5 hours, and maximum permissible driving hours in a 24 hour period varied between 11.0 and 12.0 hours. The national model legislation has been implemented in New South Wales, Victoria, Queensland and South Australia. Tasmania, Northern Territory and Australian Capital Territory have agreed but not yet implemented the legislation. Driving hour limits in Western Australia are managed slightly differently to other jurisdictions. There, driving hours are mandated under occupational health and safety legislation and the maximum continuous work time is 5 hours, with at least a 10 minute break for each five-hour work period, and drivers are also expected to have had a 7-hour minimum continuous sleep break in the last 24 hours. Though differences remain in implementation of driving hours regulation between jurisdictions, mandated driving hours are broadly similar across Australia.

## Speed limits

Up until the mid-1980s, heavy vehicles were limited to 80 kilometres per hour outside built-up areas and to posted speed limits within built-up areas. Following the 1984 *National Road Freight Industry Inquiry* report, which identified speed limit differentials between light and heavy vehicles as a contributor to poorer road safety outcomes, speed limits were increased to 100 kilometres per hour outside built-up areas for all heavy vehicles but road trains. Road train vehicles remain limited to 90 kilometres per hour under Australian vehicle standards, but Western Australia and Northern Territory permit road trains to operate up to 100 kilometres per hour.

### *Road network improvements*

Since 1971, the Commonwealth Government has invested over $24 billion (at 2009 prices) in upgrading major intercapital corridors on the National Land Transport Network (NLTN). Upgrade, re-alignment and duplication across parts of the network, combined with the increase in non-urban heavy vehicle speed limits in the mid-1980s, has significantly increased average travel speeds and reduced long-distance road freight transit times. For example, the average transit time between Sydney and Melbourne has fallen from around 15 hours in 1971 to around 11 hours today—contributing directly to improved heavy vehicle productivity and road freight industry efficiency.

### *Modelling freight productivity growth*

The report presents an aggregate dynamic model relating trends in aggregate commercial vehicle freight shares to vehicle operating costs and vehicle regulatory factors over the last 35 years. The model accurately predicts historical trends in aggregate freight shares.

The average freight cost per tonne kilometre is generally lower for larger freight vehicles, naturally advantaging these larger heavy vehicle combinations, especially for non-bulk freight moving over longer distances. Partly reflecting the natural unit cost advantage of larger freight vehicles, the marginal impact of a change in average costs or change in regulated mass limits has a relatively small effect on heavy vehicle freight shares. By far the most significant influence on the share of freight carried by different vehicle types has been the take-up of and increased network access available for six-axle articulated trucks and B-doubles.

Predicted changes in commercial vehicle freight shares may be subsequently translated into impacts on fleet-wide average loads and average vehicle kilometres travelled (VKT). The model therefore provides an aggregate predictive tool for assessing potential future growth in average vehicle freight loads—one aspect of total heavy vehicle productivity growth.

## Future prospects for freight productivity growth

With the road freight task projected to nearly double between 2010 and 2030, heavy vehicle productivity growth will influence the number of vehicles, and drivers, required to meet the future freight the task, and ultimately affecting the cost of goods transported by road freight. What are the future prospects for road freight vehicle productivity?

The report presents several possible scenarios of potential future heavy vehicle average load growth to 2030, based on varying assumptions about the take-up of current and potential future reforms.

In the absence of significant further reform to vehicle mass and dimension limits and vehicle network access, and assuming no further significant changes in relative heavy vehicle registration charges from 2010 onwards—following complete phase-in of the 2008 revisions to heavy vehicle charges—the model projects that the share of freight carried by B-doubles will continue to grow, largely at the expense of six-axle articulated trucks, plateauing at around 52 per cent of total road freight by 2030. Under this scenario the average load of articulated trucks is projected to increase from around 20.9 tonnes per vehicle kilometre in 2007 to around 21.9 tonnes per vehicle kilometre in 2030, an increase of 5 per cent, and well below the historical rate of growth.

If, instead, B-doubles' share of total freight were to increase to around 60 per cent of total road freight in 2030, again most of the additional share taken from six-axle articulated trucks, the average load across all articulated trucks would increase to around 23.5 tonnes per vehicle kilometre in 2030, an increase of 12 per cent over 2007 levels. This is equivalent to average annual growth of 0.5 per cent per annum, which is still well below the rate of growth in heavy vehicle average loads experienced over the last 15 years.

The report also considers the impact of increased take-up of higher productivity vehicles allowable under Performance Based Standards and through the Intelligent Access Program. Two scenarios are canvassed. The first scenario considers the impact of increased use of AB-triples in place of double road trains on road train accessible network roads. These vehicle combinations offer potential to carry greater mass. The model implies that the share of freight carried by AB-triples would increase to around 3 per cent by 2030, with most of the increase in AB-triple freight share taken from (double) road trains. The impact on fleet-wide average loads is, understandably, relatively muted. Fleet-wide average loads of articulated trucks are projected to be very similar to the no-further reform scenario.

The second scenario simulates the impact of granting B-triples network access to the B-double network outside built-up areas. Under this scenario, the proportion of freight carried by B-triples could potentially increase, from near negligible levels today, to almost 20 per cent of total road freight by 2030. Much of the potential freight carried by B-triples would otherwise by carried by B-doubles. Under this scenario, the fleet-wide average load of articulated trucks would increase by a further 0.5 tonnes over the no-further reform scenario, to 22.5 tonnes per vehicle kilometre by 2030. This represents an 8 per cent increase in articulated truck average loads between 2007 and 2030, at an average rate of growth of 0.3 per cent per annum—still well below the historical rate of growth in articulated truck average loads.

These scenarios are based on top-down modelling of aggregate commercial vehicle freight shares, and do not explicitly factor in heavy vehicle access restrictions. Nonetheless, the aggregate model freight shares of restricted access heavy vehicles—B-doubles, road trains and Performance Based Standards (PBS)-compliant vehicles—are reasonably consistent with the volume of freight carried across those parts of the network.

# Concluding remarks

This report shows that road freight vehicle productivity, measured by freight carried per vehicle, more than doubled between 1971 and 2007. Heavy freight vehicle productivity has increased even more rapidly, increasing by almost 600 per cent between 1971 and 2007. These improvements in road freight productivity have reduced the cost of moving freight by road, contributing, in part, to the strong growth in road freight experienced over the past four decades, and greatly improved the efficiency of freight transport in Australia.

The advent of first six-axle articulated trucks and later B-doubles has contributed significantly to the increase in average heavy vehicle productivity in Australia. Together, these two heavy vehicle classes carried nearly 70 per cent of total road freight in 2007.

With Australia's road freight task projected to continue to grow strongly, the rate of future heavy vehicle productivity growth will strongly influence the number of vehicles required to undertake the task, the number of drivers required and infrastructure implications. The modelling results presented in this report suggests that in the absence of further productivity enhancing reforms future heavy vehicle productivity growth is likely to be relatively low. Even with increased uptake of higher productivity vehicles under PBS and the Intelligent Access Program (IAP), future heavy vehicle productivity growth is likely to be much lower than recent experience.

In many respects this result should not be a surprise. The introduction and widespread take-up of first six-axle articulated trucks and then B-doubles yielded very large relative increases in average heavy vehicle payloads and heavy vehicle productivity; six-axle articulated truck average loads were typically 30 per cent higher than that of the five-axle articulated trucks they generally replaced, and B-double average loads were typically 50 per cent higher than those of the six-axle articulated trucks they replaced. These two vehicles, together with the increasing share of longer-distance freight carried by larger heavy vehicles, contributed greatly to the increases in heavy vehicle productivity experienced over the past three decades.

By comparison, B-triples and AB-triples and larger heavy vehicle combinations offer more modest potential increases in heavy vehicle payloads and so it is reasonable to expect a slowing in future road freight productivity. Nonetheless, continuing improvements in heavy vehicle productivity, through the appropriate application of larger heavy vehicles available under PBS and the IAP program, will provide important productivity benefits, helping to reduce costs and improve the competitiveness of freight-reliant industries and the broader economy.

# CHAPTER 1
# Introduction

## Key points

- Australian domestic freight activity has increased eight-fold since 1961, with over 80 per cent of additional freight carried by road or rail.
- Growth in rail freight has predominantly been due to growth in bulk commodity exports—coal and iron ore. Growth in road freight has been widespread—with strong growth in intercapital, intrastate and urban road freight.
- Productivity growth is an important contributor to rising living standards—enabling higher levels of production for given inputs. Productivity growth in one sector can reduce the average cost of that sector's output, and deliver further efficiency benefits to downstream industries and the wider economy.

## 1.1 The Australian freight task

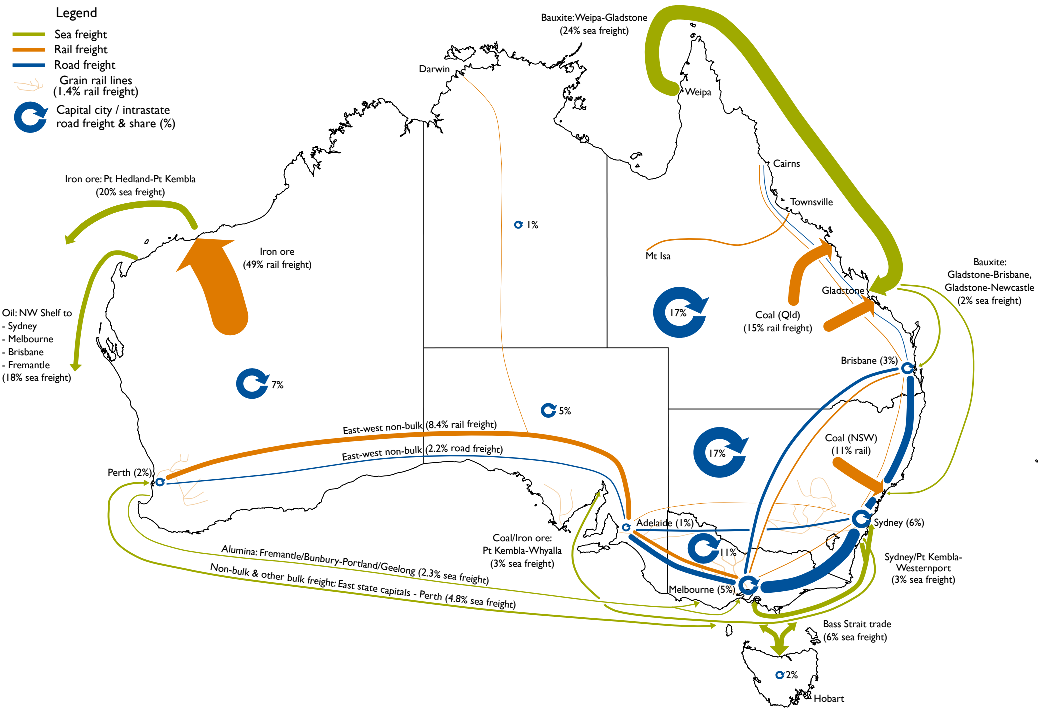
### *Current freight task*

Transport plays a significant role in the Australian economy. Rail and sea transport are essential parts of Australia's major export commodity supply chains. For example, rail movements of Australian's two largest mineral export commodities—iron ore and coal—comprise over 75 per cent of all Australian rail freight. Shipping carries significant volumes of bulk commodities around the Australian coast for further processing and refining, and is the principal mode of transport for most goods moved between Tasmania and the mainland. Road is the predominant mode of transport for urban, inter-urban and regional freight, and an integral part of container import supply chains.

Figure 1.1 stylistically illustrates Australia's major domestic freight movements in 2006–07. In particular, it highlights:

- the significance of rail freight movements of iron ore and coal, which combined account for 75 per cent of total domestic rail freight. Movement of grains account for between 2 and 3 per cent of total rail freight, depending on climatic conditions. Semi-processed and finished steel products are the other major commodity carried by rail.
- the importance of coastal shipping to the transport of domestic crude oil and petroleum, which comprise 20 per cent of total domestic sea freight, and the transport of bauxite

F1.1 Australian freight movements, 2006–07




Notes: Line widths indicate relative freight volume (tonnes). Percentages indicate the share of the total modal-specific mass-distance freight task. Figure stylistically illustrates all road freight movements, 85 per cent of all rail freight and 80 per cent of all domestic sea freight.
Source: BITRE (2009b).

and alumina from Weipa (Queensland) to Gladstone and south west Western Australia to Victoria for further processing and smelting.

- the importance of road transport for the movement of freight within urban areas (approximately 30 per cent of total freight), between capital cities (16 per cent) and other freight within each state or territory (54 per cent).

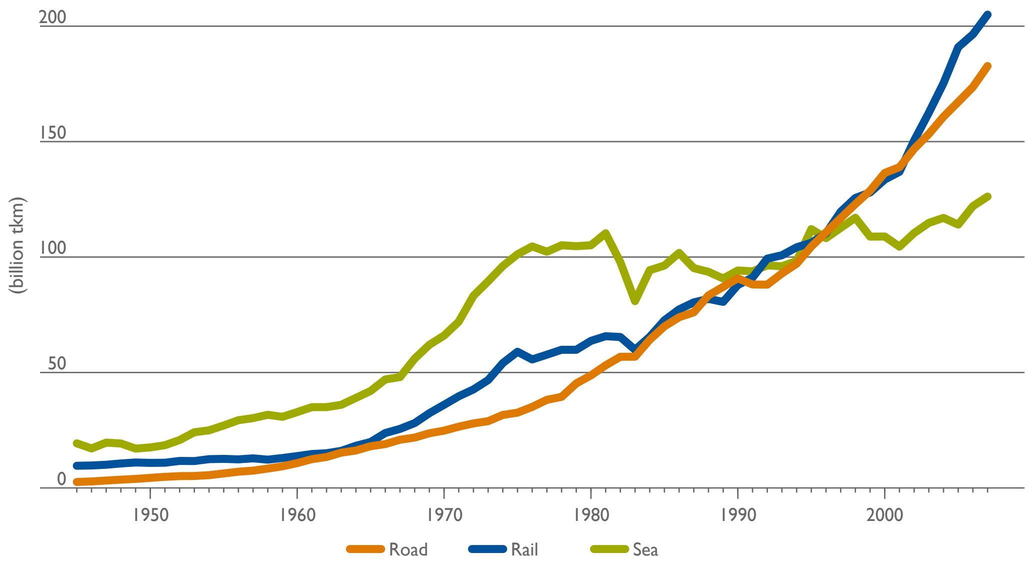
## *Historical freight growth*

The Australian freight task has grown eight-fold over the past five decades, from around 62 billion tonne kilometres in 1961 to approximately 514 billion tonne kilometres in 2006–07, an average annual growth rate of around 4.7 per cent per annum.[1] Figure 1.2 shows growth in Australian domestic freight by mode since 1945. Road freight's share of total domestic freight (measured in tonne kilometres) has grown from around 20 per cent in 1961 to around 35 per cent of total freight in 2007–08. Rail's share has increased from around 24 per cent in 1961 to 41 per cent and coastal shipping's share has fallen from around 56 per cent in 1961 to 24 per cent in 2007–08.

Growth in road freight has been influenced by a variety of factors including the changing structure of the Australian economy—reduced reliance on domestic manufacturing and increased

1 One tonne kilometre is equivalent to one tonne moved one kilometre.

F1.2 Total freight, by mode, 1945–2007




Note: Air freight volumes represent less than 0.1 per cent of total domestic freight by tonne kilometres and are not shown.
Source: BITRE estimates.

imports, increasing demand by industry for reliable and timely delivery, changing freight forwarder preferences, improvements in road infrastructure and vehicle technology, and significant regulatory changes.

Australia's iron ore and coal exports have largely grown since the early 1960s, and rail has been a key part of these export supply chains. Australian iron ore exports, and to a lesser extent coal exports, are projected to continue to grow strongly in the foreseeable future, largely underpinning projected future growth in total Australian rail freight.

Domestic coastal shipping freight increased significantly from the late 1960s and early 1970s, driven by growth in offshore oil and gas production and bauxite mining. The cessation of uneconomic domestic container shipping services in the mid-1970s and a plateauing of bulk commodity freight movements account for the lack of growth in domestic sea freight in the 1980s. The issuance of Single and Continuous Voyage Permits (SVP and CVP) in the 1990s contributed to recent growth in domestic coastal shipping freight volumes.

## 1.2 Productivity growth and transport

Productivity growth is a crucial source of increasing living standards—enabling production of more output with fewer inputs. Productivity growth adds directly to per capita national economic output. At the industry or firm level, improvements in productivity reduce production costs, which contribute to increased industry profitability and/or lower prices to consumers.

The three most common sources of productivity growth are:

- improvements in technology and/or production processes
- increased organisational efficiency of firms and industries

- resource re-allocation—at the economy-wide level reallocating resources from less to more productive sectors.

Industry scale (economies of scale and scope) can also be a source of productivity benefits—output per unit input generally increases with increasing firm size. Research and development efforts are an important source of long-term productivity enhancement. Removal of inefficient regulation and pricing distortions are an important source of improving resource allocation across the economy and provide firms with additional scope to increase their productivity and efficiency.

## *Productivity measures*

Productivity measures the quantity of outputs per unit of input. *Partial*, or single factor, productivity measures, such as labour productivity, measure the amount of output produced per unit of labour input. For an industry or single firm producing a single product, partial productivity measures can be derived for each physical input. In the transport sector, for example, productivity could be defined per unit of labour, capital, fuel or other input factor. A limitation of partial productivity measures is that they attribute all of the productivity improvement to one factor when, in fact, productivity growth may be attributable to several factors. *Total*, or multi-factor, productivity measures avoid the limitations of partial measures by measuring the growth in total output per combined unit of all factor inputs.

## *Economy-wide and transport sector productivity growth*

ABS (2010) estimates total factor productivity growth in Australia's market sector increased by approximately 1.0 per cent per year between 1985–86 and 2007–08. Over the same period, market sector labour productivity growth averaged 2.2 per cent per year and capital productivity declined slightly (see Table 1.1).

Transport and storage sector total factor productivity generally grew faster than average market industry productivity growth between 1985–86 and 2007–08, averaging 1.6 per cent per year over that period. The transport and storage sector includes for-hire businesses primarily engaged the provision of passenger and freight and associations services. Transport and storage sector labour productivity grew by 2.3 per cent per annum and capital productivity by 0.6 per cent per annum over this period.

Figure 1.3 provides a comparison of labour productivity growth across all market sectors, since 1985–86, and labour productivity growth across the entire transport and storage sector, and for major transport industry sub-sectors—*Road* and *Rail, pipelines and other transport*. (The Road and Rail, pipelines and other transport sectors not only include firms providing for-hire road and rail freight services, but also for-hire passenger services, such as taxis, private bus operators and public transport authorities.) The transport sector, and road and rail transport sub-sectors, exhibit reasonably similar labour productivity growth to market average labour productivity growth between 1985–86 and 2007–08.

## *Measuring trends in truck productivity*

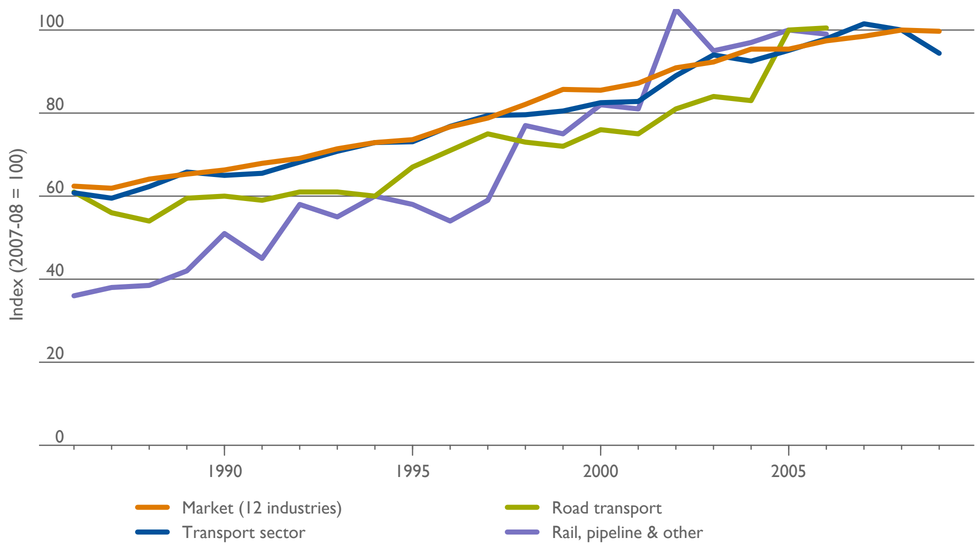
Technological change is one of the common sources of potential productivity growth. In transport, road freight vehicles represent a major source of potential productivity growth, both through increases brought about by improvements in vehicle technology—e.g. larger dimension vehicles and higher mass limits—and through changes in the mix of vehicles in the fleet.

## T1.1 Productivity growth over productivity cycles, selected industries

| Productivity measure | 1973–74 to 1981–82 | 1981–82 to 1984–85 | 1984–85 to 1988–89 | 1988-89 to 1993–94 | 1993–94 to 1998–99 | 1998–99 to 2003–04 | 2003–04 to 2007–08 | 1985–86 to 2007–08 |
|---|---|---|---|---|---|---|---|---|
| | | | | (per cent per annum) | | | | |
| **Selected market industries**[a] | | | | | | | | |
| Multi-factor productivity | 0.58 | 0.94 | 1.02 | 1.00 | 2.07 | 1.06 | –0.20 | 1.04 |
| Labour productivity | na | na | na | 2.24 | 3.29 | 2.15 | 1.19 | 2.17 |
| Capital productivity | na | na | na | –0.68 | 0.46 | –0.24 | –1.71 | –0.38 |
| **Transport and storage industry** | | | | | | | | |
| Multi-factor productivity | na | na | na | 1.73 | 2.31 | 2.43 | 1.60 | 1.59 |
| Labour productivity | na | na | na | 2.07 | 1.99 | 2.82 | 1.97 | 2.29 |
| Capital productivity | na | na | na | 1.15 | 2.79 | 1.81 | 1.04 | 0.55 |

na not available.
a. The 12 market industries include Australian New Zealand Standard Industry Classification divisions A to K and R.
Sources: ABS (2010) and BITRE estimates.

## F1.3 Transport and storage, and sub-industry multi-factor productivity, 1985–86 to 2007–08




Note The 12 market industries include Australian New Zealand Standard Industry Classification divisions A to K and R.
Sources: ABS (2007a), ABS (2010) and BITRE estimates.

This report predominantly focusses on improvements in aggregate physical freight vehicle productivity, expressed as total annual freight (tonne kilometres) per vehicle. This measure encapsulates both increases in the average load carried by freight vehicles and changes in the average intensity of use, which are both also analysed in this report. Other measures of road freight vehicle productivity that could also be considered include output per driver hour (direct labour input) or per unit of fuel used—a measure of the improvement in the average fuel efficiency of the road freight task.

### *Freight vehicle productivity and road infrastructure*

Improvements in freight vehicle productivity engendered by larger vehicles and higher mass potentially has implications for road infrastructure. All else equal, increased access for and use of larger and heavier freight vehicle combinations may increase road wear, accelerating pavement deterioration and necessitating increased road maintenance expenditure and earlier road rehabilitation. However, the implications for road pavements will depend on both the number of larger heavy vehicles and their average mass, as fewer higher mass, larger dimension vehicles are required for the same freight task, meaning fewer heavy vehicle movements across the road network per tonne of freight carried. Though some partial evidence is presented here on the potential road wear impact of recent growth in freight vehicle productivity, the report does not attempt to estimate the relationship between increasing freight vehicle productivity and road construction and maintenance expenditure.

## 1.3 Freight vehicle classifications

In this report road freight and freight vehicle productivity data are presented using several different vehicle classifications, of varying detail.

Australian road freight statistics most commonly distinguish three broad freight vehicle classes:

- *Light commercial vehicles* (LCVs) – motor vehicles of less than 3.5 tonnes gross vehicle mass (GVM) constructed for the carriage of goods.
- *Rigid trucks* – motor vehicles exceeding 3.5 tonnes GVM with a load carrying area.
- *Articulated trucks* – motor vehicles constructed primarily for load carrying, and consisting of a prime mover with a turntable device for towing a semi-trailer (ABS 2008).

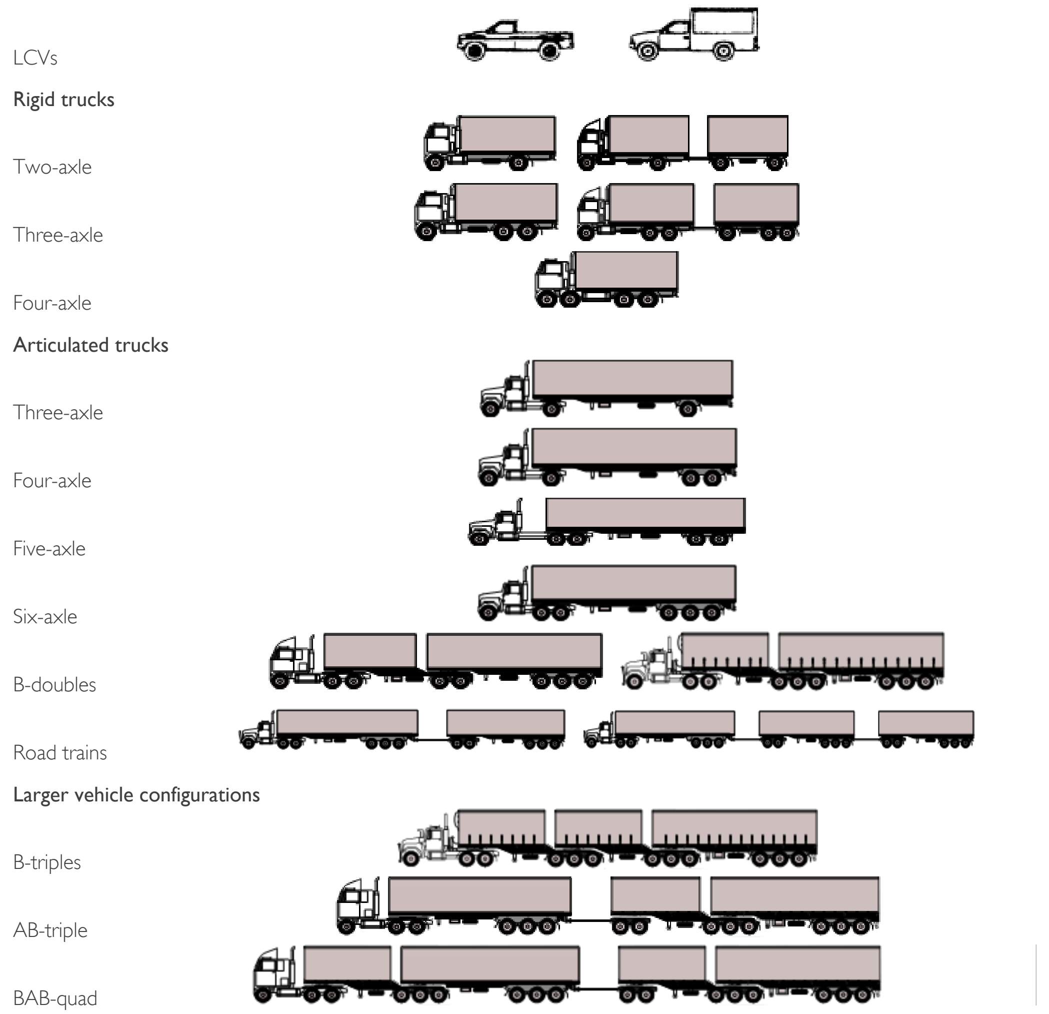
Under this classification, rigid trucks include rigid trucks towing trailers via a tow bar, draw bar or other non-articulated coupling. Articulated trucks include single-trailer and multi-trailer articulated truck combinations, such as B-doubles and road trains.

Australia's heavy vehicle charges further distinguish between *light* and *heavy* vehicles. A heavy vehicle is defined as any motor vehicle with a GVM of 4.5 tonnes or more, and includes both trucks and buses.

Within these broad classes, vehicles may be differentiated by other characteristics, such as vehicle mass, number of axles, number of trailers and/or axle configuration. The evidence presented in Chapters 3 and 4 further distinguishes freight vehicles by axle and, for articulated trucks, trailer configuration—refer to Figure 1.4. Throughout most of the report references to two-, three- and four-axle rigid trucks include rigid trucks, of the specified axle configuration, with and without trailers. B-triples, AB-triples and BAB-quad vehicle types are larger heavy vehicle combinations available under Performance Based Standards (PBS). These vehicle types are only permitted access to PBS network roads (see Figure 4.6).

The other major vehicle classification used in Australia is Austroads' vehicle classification system, which classifies vehicles according to the number of axles and axle spacing. The Austroads vehicle classification system has 10 heavy vehicle classes and two light vehicle classes. (A copy of the Austroads vehicle classification is reproduced in Appendix A.) Classified traffic count data and weigh-in-motion (WIM) data, referenced in Chapter 3, use the Austroads vehicle classification. The main difference between the Austroads' vehicle classification and the classification used throughout most of this report relates to rigid trucks towing trailers. Under the Austroads

F1.4 Vehicle types by axle and/or trailer configuration




classification, rigid trucks towing trailers are grouped with articulated trucks with a similar number of axles, whereas, throughout most of this report, rigid trucks towing trailers are classed with rigid trucks.

The National Transport Commission (NTC) classifies heavy vehicles into over 25 separate classes when determining heavy vehicle road user charges. Heavy vehicles are differentiated according to vehicle type, axle configuration, number of trailers and GVM. The NTC vehicle classification is not used elsewhere.

## 1.4 Report structure

The remainder of the report is structured as follows. Chapter 2 provides a review of trends in road freight activity and heavy vehicle productivity growth. Chapter 3 outlines the major factors that have influenced improvements in heavy vehicle productivity and provides some quantitative estimates of the relative influence of different factors. Chapter 4 outlines the prospects for future heavy vehicle productivity growth. Chapter 4 also estimates the impact of B-doubles on current average freight loads and the influence of increases in General Mass Limits (GML) on average heavy vehicle productivity. Several appendices provide supporting information.

# CHAPTER 2
# Trends in road freight

## Key points

- Total road freight increased six-fold between 1971 and 2007, equivalent to average annual growth of approximately 5.75 per cent per annum.
- Road freight growth, while remaining quite strong has declined over time, averaging 6.0 per cent per annum between 1971 and 1991 and 4.4 per cent per annum since 1991.
- Across all freight vehicle classes, average vehicle productivity (tonne kilometres per vehicle) more than doubled between 1971 and 2007. The average vehicle productivity of heavy vehicles—i.e. rigid and articulated trucks 4.5 tonnes and above—grew almost six-fold over the same period.
- Increases in freight vehicle productivity are also reflected in improvements in freight vehicle fuel efficiency. Averaged across all freight vehicles, the average rate of fuel consumption per freight tonne kilometre declined over 50 per cent between 1971 and 2007 and the average rate of fuel consumption averaged across all heavy vehicles declined by almost 50 per cent.
- Increased vehicle productivity directly reduces the average cost of freight transport, a key factor influencing growth in total road freight.

## 2.1 Trends in road freight

Since 1971, the Australian road freight task has grown from 27 billion tonne kilometres to approximately 184 billion tonne kilometres in 2007 (ABS 2008), an average annual growth rate of 5.75 per cent per annum. Some of the factors contributing to strong growth in road freight were mentioned in Chapter 1, and include:

- road infrastructure investment, particularly on intercapital and non-urban highways, which have reduced travel times and lowered costs
- removal of restrictive economic regulation applying to the road freight industry[2]
- increases in regulated vehicle mass and dimension limits.

2 Prior to the 1980s many jurisdictions regulated the range of commodities that could be carried by intrastate road transport services to limit competition with State-owned rail authorities.

- harmonisation of heavy vehicle regulations and heavy vehicle road use charges.

Other contributing factors include:

- improvements in heavy vehicle technology—e.g. engine management systems and more efficient engines
- increased use of freight logistics services and technologies—e.g. fleet vehicle tracking, computer assisted routing, etc.
- increased demand for more time-sensitive freight services.

Growth in the size and operational scope of articulated trucks, fostered by relaxation of vehicle mass and dimension regulations, has arguably helped spur road freight growth by significantly lowering the average cost of road freight transport. Articulated trucks' share of total road freight has increased from around 55 per cent in 1971 to around 78 per cent by 2007. Over that period, articulated truck average loads have more than doubled, from 9.7 tonnes per vehicle kilometre to over 20 tonnes per vehicle kilometre, and the average distance travelled by articulated trucks has increased almost 90 per cent to over 90 000 kilometres per annum.

## *Road freight by vehicle type*

Figure 2.1 shows the Survey of Motor Vehicle Use (SMVU) estimates of the road freight task, by broad commercial vehicle type—light commercial vehicles (LCVs), rigid trucks and articulated trucks—between 1971 and 2007. Articulated truck freight volumes have grown significantly faster than LCV or rigid truck volumes, averaging 6.4 per cent per annum since 1971. Over the same period, freight carried by rigid trucks has increased by around 3.2 per cent per annum and freight carried by LCVs by 5.3 per cent per annum. By 2007, articulated trucks accounted for 78 per cent of total road freight tonne kilometres, while rigid trucks comprised 18 per cent and LCVs 4 per cent.

## *Road freight by vehicle class and axle configuration*

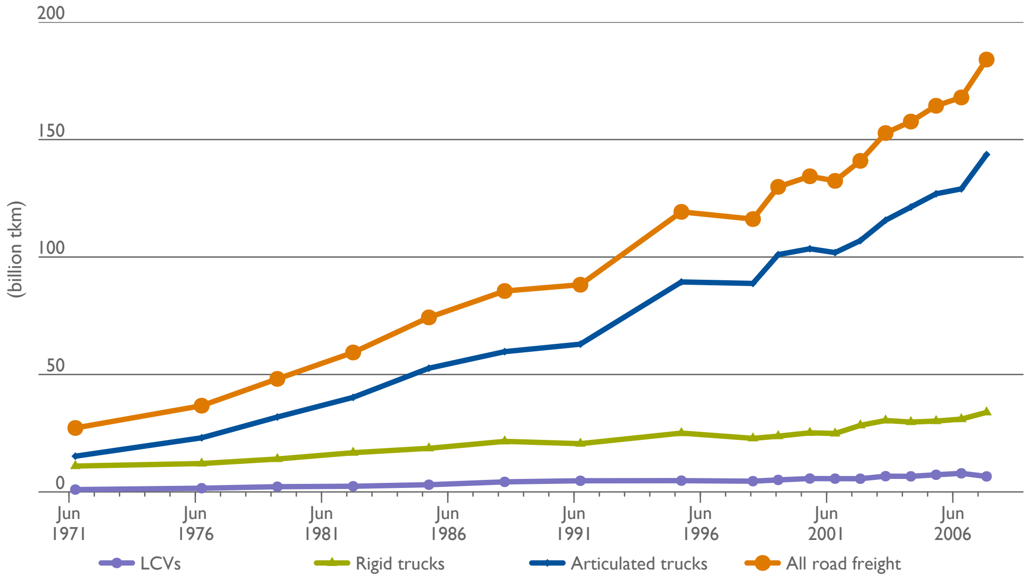
Stronger growth in articulated truck freight has been partly fuelled by vehicle substitution—that is, operators switching from rigid trucks to larger articulated truck combinations—and partly by stronger growth in freight demand in those markets in which articulated trucks dominate, particularly intercapital non-bulk freight.

Figure 2.2 shows the road freight share split into six broad vehicle type/axle configuration classes:

- LCVs
- rigid trucks
- less than 6-axle single trailer articulated trucks
- 6-or-more axle single trailer articulated trucks
- B-doubles
- road trains.

It illustrates that, up until very recently, single trailer articulated trucks have been the predominant articulated truck type used for hauling road freight, with almost 60 per cent of total road freight in 1998. However, since the introduction of B-doubles in the late 1980s, the share of road freight

F2.1 Total road freight by commercial vehicle type, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

carried by single trailer articulated trucks has declined and the share of road freight carried by B-doubles has increased to around 32 per cent of total road freight in 2007, supplanting single trailer articulated trucks as the predominant vehicle type for road freight transport. Road trains have been operating in remote areas in Australia since the Second World War. Since 1971, the share of road freight carried by road trains has increased from around 5 per cent to around 17 per cent (±2 per cent).

Between 1971 and 1998, rigid trucks' share of the total road freight task fell from around 40 per cent to 20 per cent. Since 1998, the share of road freight carried by rigid trucks has remained more or less around 20 per cent. The share of freight carried by two-axle rigid trucks, which includes two-axle rigid trucks towing trailers, has declined from near 30 per cent of total road freight in 1971 to 6 per cent in 2007. The share of road freight carried by three-axle rigid trucks, which includes three-axle rigid trucks towing trailers has increased from around 6 per cent in 1971 to around 10 per cent in 2007. And four-axle rigid trucks have generally carried less than 5 per cent of total road freight, and in 2007 accounted for less than 2 per cent of total road freight.

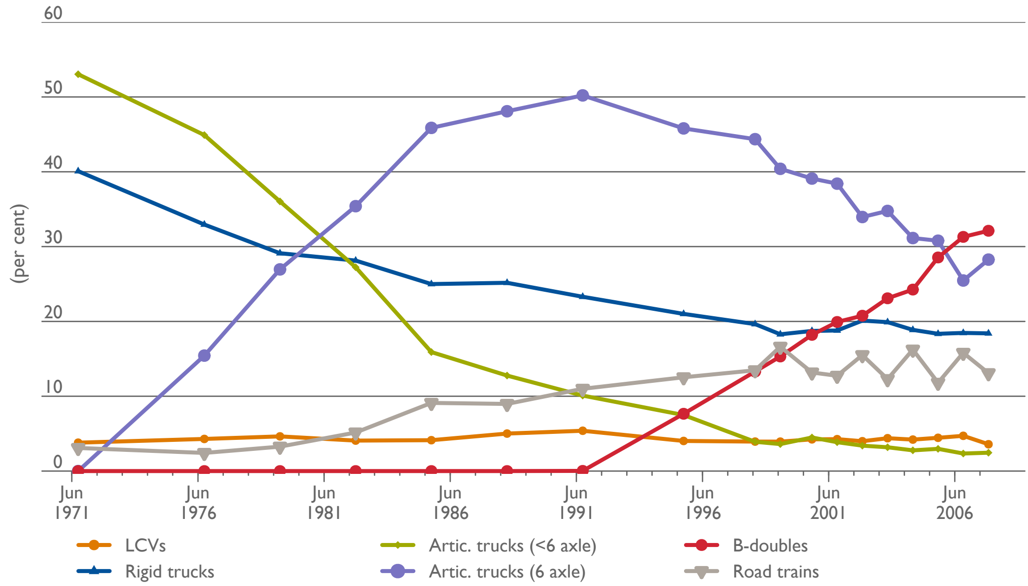
Freight carried by LCVs has remained between 4 and 5 per cent of total road freight. A large proportion of this 'freight' is 'tools of trade' (i.e. tradesman's tools and supplies), rather than goods being transported between different parts of the supply chain.

## *Urban and non-urban road freight*

Urban road freight, including freight moved in capital cities and provincial urban areas,[3] accounts for around 31 per cent of total road freight in Australia. Growth in urban road freight averaged

3 Provincial urban areas for road use data include Statistical Districts with a population greater than 40 000 or clusters of Census Collection Districts and other urban areas with a population greater than 40 000, based on the 2001 Population Census (ABS 2008). The set of provincial urban areas has expanded over time, reflecting increases in population.

F2.2 Total road freight by broad vehicle type and vehicle axle configuration, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

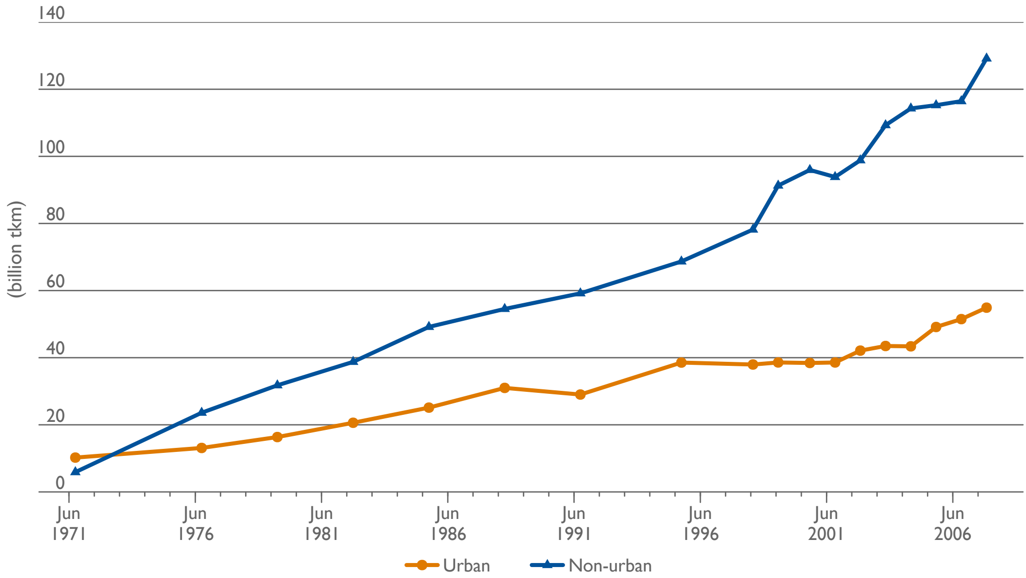
approximately 4.7 per cent per annum between 1976 and 2007, slightly slower than growth in total road freight. Road freight in the eight state and territory capital cities grew by 4.3 per cent per annum between 1976 and 2007. (These urban road freight growth estimates are inflated slightly by the expansion in the geographic coverage of provincial urban areas in the SMVU since 1971.)

The non-urban road freight task, accordingly, grew by around 5.6 per cent per annum between 1976 and 2007, above the average rate of growth in total road freight. Figure 2.3 shows the SMVU estimates of the urban and non-urban road freight task between 1971 and 2007.

According to the latest SMVU estimates, in 2007 articulated trucks were responsible for half of total road freight movements (in tonne kilometre terms) in urban areas, accounting for approximately 49 per cent of freight in capital cities and 57 per cent in provincial urban areas. (Figure 2.4 shows that articulated trucks have been responsible for the majority of road freight in capital cities since 1995.) Outside urban areas, articulated trucks are responsible for 88 per cent of total road freight, and almost 100 per cent of interstate road freight (ABS 2007b, and BTRE estimates).

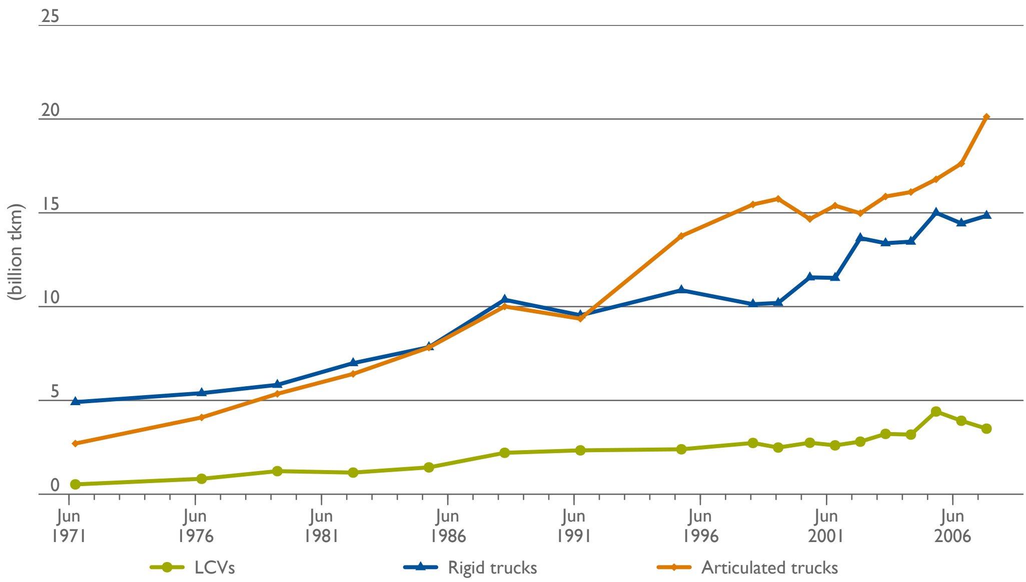
Between 1990 and 2002, the share of freight carried by LCVs in urban areas remained unchanged at around 10.5 per cent. The total amount of heavy truck traffic (i.e. excluding LCVs) in urban areas has not grown significantly, with almost all growth being accounted for by substitution from rigid to articulated trucks. Indeed, growth in heavy vehicle use (vehicle kilometres travelled) has been slower than growth in total road use. Also, the average load of articulated trucks in urban areas has not grown significantly, presumably because the nature of the task and limited road network access in urban areas render substitution to larger heavy vehicle configurations (e.g. B-doubles) less economically attractive.

F2.3 Road freight by area of operation, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

F2.4 Capital city road freight, by vehicle type, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

## *Road freight by commodity*

The mix of commodities carried by road freight also potentially influences trends in road freight activity. The SMVU also provides measures of road freight by commodity type:

### T2.1 Road freight share, by broad commodity class, 1971, 1991 and 2007

| Commodity class | 1971 | 1991 | 2007 |
|---|---|---|---|
| | | (per cent) | |
| Food and live animals | 17.0 | 14.8 | 13.3 |
| Beverages and tobacco | 1.3 | 1.1 | 1.4 |
| Crude materials, inedible, except fuels | 33.1 | 33.5 | 37.7 |
| Mineral fuels, lubricants and related materials | 10.6 | 6.8 | 5.6 |
| Animal and vegetable oils, fats and waxes | 0.6 | 0.5 | 0.5 |
| Chemicals and related products, nes | 1.0 | 2.2 | 2.2 |
| Manufactured goods | 20.1 | 25.7 | 21.4 |
| Tools of trade | 4.9 | 4.6 | 6.0 |
| Other commodities nes and unspecified | 11.4 | 10.8 | 12.0 |
| Total | 100 | 100 | 100 |

Sources: ABS (2008, and earlier issues) and BITRE estimates.

- total tonnages uplifted, by broad commodity class
- total tonne kilometres, by broad commodity class.

Although the published SMVU commodity classes have varied over time with some limited assumptions they may be condensed to the following 10 commodity groups:

- Food and live animals
- Beverages and tobacco
- Crude materials, inedible, except fuels
- Mineral fuels, lubricants and related materials
- Animal and vegetable oils, fats and waxes
- Chemicals and related products not elsewhere specified (nes)
- Manufactured goods
- Tools of trade
- Other commodities nes
- Unspecified

Table 2.1 shows the share of total tonnes uplifted by broad commodity group in 1971, 1991 and 2007. In tonnage terms, inedible crude materials—which includes metallic and non-metallic ores, wood, pulp and waste paper and other crude materials—comprise the largest share of total tonnes uplifted by road, generally between 30 and 40 per cent of total tonnages. Manufactures and food, beverages and tobacco (and animal and vegetable oils, fats and waxes) account for around 20 per cent of total tonnes uplifted by road between 1971 and 2007. The share of food, beverages and tobacco has remained relatively stable over the 35-year period. Manufactures' share of total tonnages uplifted increased significantly through the 1980s, to be 26 per cent of total road freight tonnes in 1991, but has since declined back to near 20 per cent. Mineral fuels (including coal and coke and other petroleum products) have declined from around 10 per cent of total road freight tonnages in the 1970s to around 5–6 per cent since 2000. 'Tools of trade' has generally comprised between 4 and 6 per cent of total road freight tonnages.

Table 2.2 shows the share of road freight tonnages by broad commodity group in 2007, for each of LCVs, rigid trucks and articulated trucks. The data shows that articulated trucks carry

**T2.2** Road freight share, by broad commodity class and vehicle class, 2007

| Commodity class | LCVs | Rigid trucks | Articulated trucks |
|---|---|---|---|
| | (per cent) | | |
| Food and live animals | 5.6 | 7.0 | 21.7 |
| Beverages and tobacco | 1.3 | 0.7 | 2.0 |
| Crude materials, inedible, except fuels | 2.7 | 51.7 | 28.4 |
| Mineral fuels, lubricants and related materials | 1.6 | 3.2 | 9.0 |
| Animal and vegetable oils, fats and waxes | 0.0 | 0.3 | 0.8 |
| Chemicals and related products, nes | 3.6 | 1.2 | 3.0 |
| Manufactured goods | 19.2 | 21.6 | 21.7 |
| Tools of trade | 51.8 | 3.6 | 0.5 |
| Other commodities nes and unspecified | 14.2 | 10.6 | 13.0 |
| Total | 100 | 100 | 100 |

Sources: ABS (2008, and earlier issues) and BITRE estimates.

freight from across a broad mix of commodities. Food and live animals comprise 22 per cent of freight carried by articulated trucks, crude materials 28 per cent, mineral fuels 9 per cent, manufactured goods 22 per cent and other commodities 13 per cent. Crude materials (e.g. building materials, sand, stone and gravel) are the main commodity type carried by rigid trucks. Manufactured goods comprise 22 per cent of rigid truck commodities carried. Tools of trade are the main type of 'freight' carried by LCVs. Food and live animals, manufactured goods and other goods are the other major commodity types carried by LCVs.

While the relative mix of commodities carried by road freight has changed only marginally over time, the average distance each tonne of freight moved increased rapidly through the 1970s and 1980s, particularly for articulated trucks. This trend is indicative of more rapid growth in long-distance road freight. Figure 2.5 shows that the average haulage distance for freight moved by articulated trucks increased from below 100 kilometres per tonne in 1971 to over 150 kilometres per tonne of freight in 1991. Since then, ignoring the evident inter-sample variability, the average haulage distance per tonne of freight has remained more or less around 160 kilometres per tonne. Although it is less evident, the average haulage distance of freight moved by rigid truck and LCVs also increased significantly in the 1970s and 1980s, and since then has remained more or less around 35 kilometres per tonne for rigid trucks and 50 kilometres per tonne for LCVs. (The average haulage distance for LCVs appears high, but this is because the average freight load per vehicle kilometre is typically around 0.2 tonnes.)

## 2.2 Freight vehicle productivity trends

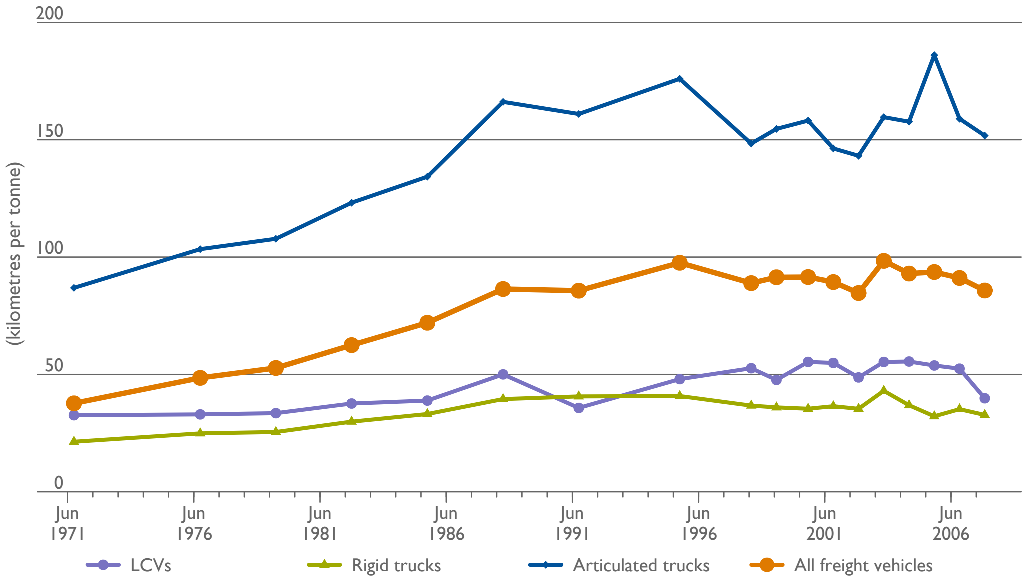
Freight vehicle productivity is defined as freight per vehicle, and comprises two components:

- average vehicle load—freight per vehicle kilometre
- average vehicle utilisation—annual vehicle kilometres per vehicle.

### *Average vehicle use trends*

Figure 2.6 shows the average vehicle kilometres travelled (VKT) travelled by LCVs, rigid trucks and articulated trucks between 1971 and 2007. Articulated truck average VKT increased from around 50 000 kilometres in 1971 to over 90 000 kilometres in 2007, an annual average growth rate of 1.8 per cent per annum. Over the same period, average vehicle kilometres travelled by

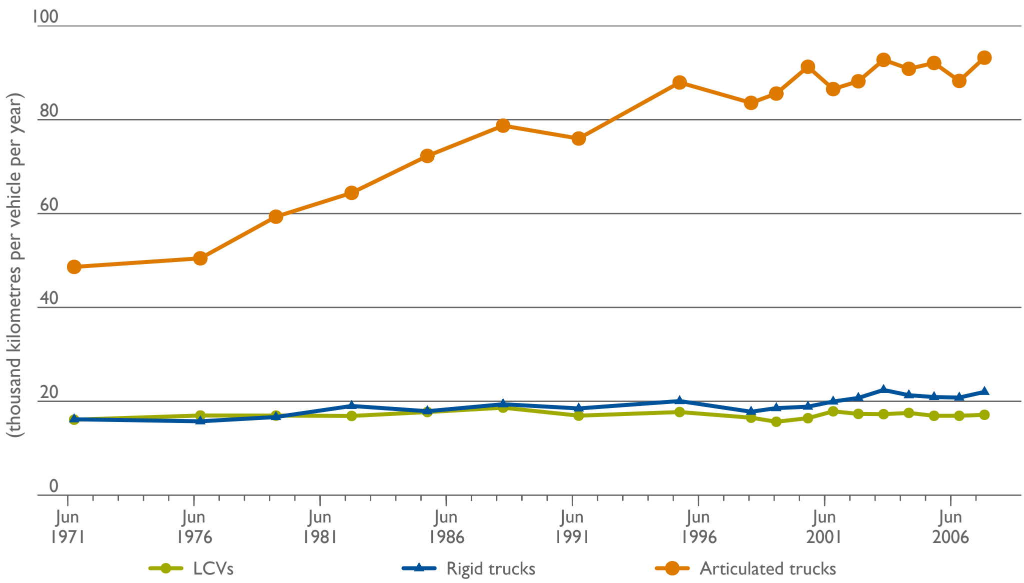
F2.5 Average freight haulage distance, by broad vehicle type, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

rigid trucks increased from 16 200 kilometres per annum to 22 000 kilometres per annum, an average increase of 0.86 per cent per annum, and the average vehicle kilometres travelled of LCVs has increased slightly, from 16 100 kilometres per annum to 17 100 kilometres per annum.

F2.6 Average vehicle kilometres travelled by vehicle type, 1971–2007



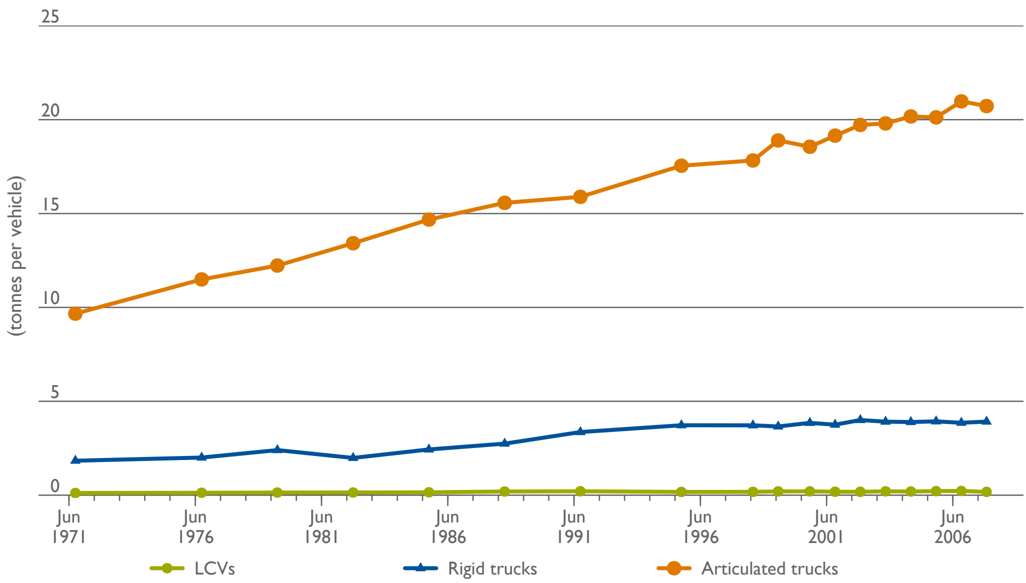

Sources: ABS (2008, and earlier issues) and BITRE estimates.

Growth in average utilisation has been less rapid since 1991 for articulated trucks. Since 1991, articulated truck average vehicle kilometres travelled has increased by approximately 1.3 per cent per annum, from 76 000 kilometres per annum in 1991. Rigid truck average vehicle kilometres travelled has increased slightly more rapidly since 1991, by an average of 1.1 per cent per annum, from approximately 18 500 kilometres per annum.

## *Average load trends*

Average loads have also increased significantly across all vehicle classes over the past 30 years. Between 1971 and 2007, for example, the average load of articulated trucks increased by over 100 per cent, from 9.7 tonnes (per vehicle kilometres travelled) to 20.7 tonnes—an average annual increase of 2.1 per cent per annum (see Figure 2.7). The average load carried by rigid trucks also increased significantly, from around 1.8 tonnes in 1971 to 3.9 tonnes in 2007, and the average load of LCVs increased from 0.12 tonnes in 1971 to 0.2 tonnes in 2007. (The measured increase in LCV and rigid truck vehicle average is affected by two changes in vehicle classification that occurred between 1971 and 1991, which resulted in some vehicles that were previously classed as rigid trucks reclassified as LCVs. These classification changes slightly increased the average load of both vehicle classes—inflating the estimated growth in LCV average loads and diminishing the estimated growth of rigid truck average loads.)

**F2.7** Average load by commercial vehicle type, 1971–2007




Sources: ABS (2008, and earlier issues) and BITRE estimates.

Like the trend in average vehicle kilometres travelled, the growth in average loads has been less pronounced since 1991. For articulated trucks, average loads have increased by around 1.7 per cent per annum, from 15.9 tonnes, since 1991. Similarly, rigid truck average loads have increased by around 1.0 per cent per annum since 1991.

**T2.3** Commercial vehicle productivity summary – 1971, 1991 and 2007

| Vehicle type | Freight (million tkm) | Avg. load (t) | Avg. VKT (km) | No. veh. ('000 veh.) |
|---|---|---|---|---|
| | | **1971** | | |
| LCVs | 1 006 | 0.12 | 16.1 | 532.7 |
| Rigid trucks | 11 015 | 1.84 | 16.2 | 371.1 |
| Articulated trucks | 15 208 | 9.67 | 48.7 | 32.3 |
| All vehicles | 27 228 | 1.68 | 17.2 | 936.1 |
| | | **1991** | | |
| LCVs | 4 752 | 0.21 | 17.0 | 1346.4 |
| Rigid trucks | 20 547 | 3.36 | 18.5 | 330.8 |
| Articulated trucks | 62 906 | 15.89 | 76.0 | 52.1 |
| All vehicles | 88 204 | 2.68 | 19.0 | 1729.3 |
| | | **2007** | | |
| LCVs | 6 597 | 0.18 | 17.1 | 2 183.5 |
| Rigid trucks | 33 873 | 3.92 | 22.0 | 392.8 |
| Articulated trucks | 143 601 | 20.72 | 93.2 | 74.3 |
| All vehicles | 184 071 | 3.48 | 20.0 | 2 650.6 |

Sources: CBCS (1973), ABS (1993), ABS (2008).

### *Vehicle numbers*

The number of commercial vehicles required to undertake the road freight task has grown nowhere near as fast as the rate of growth in the freight task, largely due to increased heavy vehicle productivity—increases in average loads, increased average vehicle utilisation and substitution to larger trucks. The average annual growth in truck numbers between 1971 and 1991 averaged 2.4 per cent per annum for articulated trucks, –0.5 per cent per annum for rigid trucks and 4.7 per cent per annum for LCVs. Between 1991 and 2007, the number of articulated trucks increased by approximately 2.3 per cent per annum the number of rigid trucks by 1.1 per cent per annum and the number of LCVs by 3.1 per cent per annum.

### *Productivity growth*

Tables 2.3 and 2.4, which summarise commercial vehicle productivity in 1971, 1991 and 2007, and commercial vehicle productivity growth between those years, highlight the strong growth in heavy vehicle productivity growth over that time. Between 1971 and 1991, heavy vehicle productivity tripled, equivalent to average annual growth of 6.24 per cent per annum. Average loads increased grew by 140 per cent (4.5 per cent per annum) and average vehicle utilisation by 40 per cent (1.7 per cent per annum). Since 1991, however, total heavy vehicle productivity has grown only 74 per cent (3.5 per cent per annum). Average loads have grown by 38 per cent (2.0 per cent per annum) and average vehicle utilisation 27 per cent (1.5 per cent per annum).

## 2.3 Commercial vehicle productivity decomposition

An important element of the increase in total heavy vehicle productivity is the increase in the proportion of freight carried by larger vehicle classes. The relative contribution of changes in the share of freight carried by different vehicle types, and growth in within-class average loads and vehicle utilisation may be derived by decomposing productivity growth into its constituent parts. (Appendix B provides a derivation of the commercial vehicle productivity decomposition

**T2.4** Commercial vehicle productivity growth, 1971–2007

| Vehicle type | Productivity growth | | Average load | | Average VKT | |
|---|---|---|---|---|---|---|
| | (%) | (% pa) | (%) | (% pa) | (%) | (% pa) |
| | | | **1971–2007** | | | |
| LCVs | 60 | 1.31 | 50 | 1.14 | 6 | 0.17 |
| Rigid trucks | 191 | 3.01 | 114 | 2.13 | 36 | 0.86 |
| Articulated trucks | 311 | 4.00 | 114 | 2.14 | 92 | 1.82 |
| All commercial vehicles | 139 | 2.45 | 106 | 2.03 | 16 | 0.41 |
| All heavy vehicles | 484 | 5.03 | 229 | 3.36 | 78 | 1.61 |
| | | | **1971–1991** | | | |
| LCVs | 87 | 3.18 | 77 | 2.91 | 5 | 0.26 |
| Rigid trucks | 109 | 3.76 | 83 | 3.07 | 14 | 0.67 |
| Articulated trucks | 157 | 4.83 | 64 | 2.51 | 56 | 2.25 |
| All commercial vehicles | 75 | 2.85 | 59 | 2.35 | 10 | 0.49 |
| All heavy vehicles | 235 | 6.24 | 139 | 4.46 | 40 | 1.70 |
| | | | **1991–2007** | | | |
| LCVs | –14 | –0.97 | –15 | –1.03 | 1 | 0.07 |
| Rigid trucks | 39 | 2.07 | 17 | 0.96 | 19 | 1.10 |
| Articulated trucks | 60 | 2.98 | 30 | 1.67 | 23 | 1.28 |
| All CVs | 36 | 1.95 | 30 | 1.63 | 5 | 0.31 |
| All heavy vehicles | 74 | 3.53 | 38 | 2.01 | 27 | 1.49 |

Sources: CBCS (1973), ABS (1993), ABS (2008) and BITRE estimates.

used here.) The freight share term captures the contribution to productivity growth of changes in the size of the fleet, and the load and VKT terms indicate the relative contribution to overall vehicle productivity of increases in average loads and average VKT, respectively.

Table 2.5 shows the vehicle productivity decomposition for road freight vehicles in Australia between 1971 and 2007, and the two sub-periods, 1971–1991 and 1991–2007. The decomposition provides some further insights into the relative contribution of changes in fleet composition, average loads and average vehicle kilometres travelled to total freight vehicle productivity growth.

Considering first the contribution to total freight vehicle productivity growth of each broad vehicle class, Table 2.5 shows that articulated trucks have contributed approximately 94 per cent of the growth in total physical vehicle productivity since 1971. Despite growth in average loads and average vehicle utilisation, rigid trucks have contributed less than 3 per cent to total commercial vehicle productivity growth. LCVs contributed approximately 3.5 per cent to improved freight vehicle productivity over this period.

The vehicle share impact reflects the productivity-weighted relative contribution of changes in the number of vehicles on overall freight vehicle productivity. (The total vehicle share effect, summed across all commercial vehicle classes, is zero.) The sign of the vehicle share effect is positive for those vehicle classes where vehicle numbers have grown at above average vehicle growth rates—LCVs only—and negative for those vehicles classes where the number of vehicles in the fleet has grown at below average commercial vehicle growth rates—rigid and articulated trucks. The share impact of LCVs is small and positive, 1.5 per cent, the combined product of significant growth in the number of LCVs in the fleet but small average productivity impact of a single LCV. The vehicle share impacts of rigid and articulated trucks, –36 per cent and –19 per cent, are larger in absolute magnitude but negative, indicating that fleet-average productivity growth has been dampened by below average growth in the number of these vehicles in the

**T2.5** Commercial vehicle productivity decomposition, 1971–2007

| Vehicle type | Share | Productivity | Productivity components: Load | VKT | Total |
|---|---|---|---|---|---|
| | (per cent) | | | | |
| **1971–2007** | | | | | |
| LCVs | 1.5 | 2.0 | 1.7 | 0.3 | 3.5 |
| Rigid trucks | −35.6 | 38.2 | 26.8 | 11.3 | 2.5 |
| Articulated trucks | −19.3 | 113.3 | 60.8 | 52.5 | 94.0 |
| All commercial vehicles | 0.0 | 100.0 | 82.5 | 17.5 | 100.0 |
| All heavy vehicles[a] | 0.0 | 100.0 | 65.6 | 34.4 | 100.0 |
| **1971–1991** | | | | | |
| LCVs | 2.6 | 5.0 | 4.6 | 0.4 | 7.6 |
| Rigid trucks | −43.0 | 43.5 | 35.4 | 8.0 | 0.5 |
| Articulated trucks | −16.8 | 108.7 | 57.2 | 51.5 | 91.8 |
| All commercial vehicles | 0.0 | 100.0 | 82.3 | 17.7 | 100.0 |
| All heavy vehicles[a] | 0.0 | 100.0 | 71.1 | 28.9 | 100.0 |
| **1991–2007** | | | | | |
| LCVs | 0.8 | −2.2 | −2.4 | 0.1 | −1.4 |
| Rigid trucks | −17.3 | 22.2 | 10.4 | 11.8 | 4.9 |
| Articulated trucks | −17.7 | 114.3 | 64.5 | 49.7 | 96.5 |
| All commercial vehicles | 0.0 | 100.0 | 83.9 | 16.1 | 100.0 |
| All heavy vehicles[a] | 0.0 | 100.0 | 57.3 | 42.7 | 100.0 |

a Relative to growth in heavy vehicle freight.
Sources: CBCS (1973), ABS (2007b) and BITRE estimates.

fleet.

Considering the productivity terms, the productivity decomposition shows that averaged across all commercial vehicles increases in average vehicles loads contributed over 80 per cent of total freight vehicle productivity growth between 1971 and 2007, and increased average vehicle utilisation just under 20 per cent. Averaged across rigid and articulated trucks only—'All heavy vehicles'—the decomposition implies that increased average loads contributed approximately two-thirds of total heavy vehicle productivity growth between 1971 and 2007, with the remainder due to increased average vehicle utilisation. In other words, growth in average vehicle loads has had a larger influence on overall commercial vehicle productivity than growth in average vehicle utilisation.

Within each vehicle class the relative contribution of average load and average VKT to overall productivity growth is generally more evenly distributed. For articulated trucks, the productivity decomposition implies that approximately 54 per cent of the growth in average vehicle productivity since 1971 is due to load growth and 46 per cent to growth in average VKT. For rigid trucks, however, the relative contributions of increased loads and VKT are 70 per cent and 30 per cent, respectively.

These results are reasonably similar across the two sub-periods: 1971–1991 and 1991–2007. Articulated trucks are responsible for over 90 per cent of total commercial vehicle productivity growth. Across all commercial vehicles, and also for heavy vehicles, growth in average vehicle loads has had a larger impact on overall productivity growth than growth in average VKT.

## Growth in urban and non-urban freight traffic

Section 2.1 noted that non-urban road freight has grown more strongly than urban freight over the last three decades. The same productivity growth decomposition can be applied separately to urban and non-urban road freight to identify differences in the sources of urban and non-urban freight growth.

Table 2.6 provides a comparison of capital city and non-urban road freight productivity growth between 1991 and 2006. Several features stand out. Firstly, non-urban road freight productivity growth has been much higher than that of capital city road freight, the former averaged 4.9 per cent per annum between 1991 and 2006 versus 1.4 per cent per annum for capital city productivity growth. This is also reflected in productivity growth for each broad freight vehicle class. Articulated truck productivity grew by 4.1 per cent per annum for non-urban freight and by 2.6 per cent per annum within capital cities. The story is similar for rigid trucks—rigid truck productivity for freight movements outside urban areas grew twice as fast that of capital city rigid truck productivity.

Across all rigid and articulated trucks, total productivity of vehicles carrying freight outside urban areas grew 130 per cent between 1991 and 2006, whereas capital city heavy vehicle productivity grew by 47 per cent.

**T2.6** Capital city and non-urban commercial vehicle productivity growth, 1991–2006

| Vehicle type | Productivity growth | | Avg. load | | Avg. VKT | |
|---|---|---|---|---|---|---|
| | *(%)* | *(% pa)* | *(%)* | *(% pa)* | *(%)* | *(% pa)* |
| | | | Capital cities | | | |
| LCVs | 16 | 0.97 | 9 | 0.57 | 6 | 0.40 |
| Rigid trucks | 35 | 2.04 | 13 | 0.82 | 20 | 1.22 |
| Articulated trucks | 47 | 2.60 | 20 | 1.25 | 22 | 1.33 |
| All commercial vehicles | 22 | 1.35 | 13 | 0.83 | 8 | 0.52 |
| All heavy vehicles | 48 | 2.67 | 23 | 1.37 | 21 | 1.28 |
| | | | Non-urban areas | | | |
| LCVs | 45 | 2.51 | 8 | 0.51 | 34 | 1.98 |
| Rigid trucks | 70 | 3.59 | 20 | 1.22 | 41 | 2.33 |
| Articulated trucks | 83 | 4.11 | 35 | 2.01 | 36 | 2.06 |
| All commercial vehicles | 103 | 4.85 | 46 | 2.58 | 39 | 2.22 |
| All heavy vehicles | 130 | 5.72 | 46 | 2.57 | 57 | 3.06 |

Sources: CBCS (1973), ABS (2007b) and BITRE estimates.

The relative contribution of growth in articulated truck average loads and vehicle utilisation to overall productivity growth are more or less evenly distributed for both capital city and non-urban freight. Capital city articulated truck average loads and average VKT each increased by around 20 per cent between 1991 and 2006, and non-urban articulated truck average loads and average VKT each increased by around 35 per cent over the same period. For rigid trucks, growth in average vehicle utilisation has made a slightly larger contribution to total productivity growth than increases in average loads.

Table 2.7 shows the productivity decomposition for capital city and non-urban freight, by vehicle type between 1991 and 2006. For non-urban freight, articulated trucks are responsible for over 90 per cent of total productivity growth, and rigid trucks contributed around 5 per cent of total productivity growth. In capital cities, by contrast, articulated trucks contributed approximately 71 per cent of total productivity growth, rigid trucks 19 per cent and LCVs 10 per cent. The

**T2.7** Capital city and non-urban commercial vehicle productivity decomposition, 1991–2006

| Vehicle type | Share | Productivity effects Load | VKT | Total prod. | Total |
|---|---|---|---|---|---|
| | (per cent) | | | | |
| **Capital cities** | | | | | |
| LCVs | 2.6 | 7.7 | 4.50 | 3.18 | 10.3 |
| Rigid trucks | –52.9 | 71.5 | 28.75 | 42.72 | 18.6 |
| Articulated trucks | –21.6 | 92.7 | 44.94 | 47.78 | 71.1 |
| All heavy vehicles | –103.8 | 193.5 | 99.92 | 93.58 | 89.7 |
| All commercial vehicles | 0.0 | 100.0 | 61.58 | 38.42 | 100 |
| **Non-urban areas** | | | | | |
| LCVs | 0.1 | 1.4 | 0.29 | 1.10 | 1.5 |
| Rigid trucks | –4.4 | 9.5 | 3.31 | 6.23 | 5.2 |
| Articulated trucks | 27.0 | 66.3 | 32.75 | 33.57 | 93.3 |
| All heavy vehicles | –23.4 | 121.8 | 55.83 | 66.02 | 98.5 |
| All commercial vehicles | 0.0 | 100.0 | 53.64 | 46.36 | 100 |

Sources: CBCS (1973), ABS (2007b) and BITRE estimates.

other interesting feature is that the vehicle share effect is positive for articulated trucks outside urban areas.

## 2.4 Other freight productivity trend measures

Other partial heavy vehicle productivity measures include labour productivity, measured relative to either driver hours or total hours worked, and freight per unit of fuel use.

Although comprehensive statistics are not available on total commercial vehicle driver hours, it is possible to put a lower bound on the growth in productivity per driver hour. For example, assuming constant average commercial vehicle speeds, growth in freight productivity per driver hour will be identical to average load growth. However, with longer distance freight increasing as a share of total road freight, average commercial vehicle speeds are likely to have increased over the past three decades, implying shorter average travel times per vehicle kilometre and higher growth in freight per driver hour. Therefore, growth in road freight productivity per driver hour will have been above growth in average truck loads.

The fuel efficiency of the road freight task has also increased appreciably over the last three decades, reducing carbon emissions per unit of freight. Table 2.8 shows the average rate of fuel consumption, per vehicle kilometre travelled, across all articulated trucks increased by approximately 8 per cent between 1971 and 2007—from 45.7 to 49.5 litres per 100 kilometres—while over the same period the average rate of fuel consumption for rigid trucks increased by 12 per cent—from 23.3 to 26.0 litres per 100 kilometres. However, expressed relative to the freight task, the average rate of fuel consumption actually declined by around 44 per cent, between 1971 and 2007, across each commercial vehicle class. When combined with the increasing share of freight carried by larger heavy vehicles, which are more fuel efficient per tonne kilometre, overall road freight fuel efficiency has improved 56 per cent since 1971. Future improvement in freight vehicle productivity will also improve the average fuel efficiency of road freight transport.

This chapter has provided a broad overview of trends in Australian freight vehicle productivity and highlighted the relative contribution of trends in vehicle freight share and growth in average

**T2.8** Fuel consumption per freight tonne kilometre, 1971–2007

| Vehicle type | Fuel consumption rate | | | | Fuel economy improvement | |
|---|---|---|---|---|---|---|
| | Per VKT | | Per TKM | | | |
| | 1971 | 2007 | 1971 | 2007 | 1971–2007 | |
| | *(L/100 km)* | | *(L/100 tkm)* | | *(%)* | *(% pa)* |
| LCVs | 12.8 | 12.8 | 108.7 | 60.7 | −44.2 | −1.61 |
| Rigid trucks | 23.3 | 26.0 | 12.7 | 7.2 | −42.9 | −1.54 |
| Articulated trucks | 45.7 | 49.5 | 4.7 | 2.7 | −43.8 | −1.59 |
| All CVs | 27.9 | 36.4 | 8.1 | 3.5 | −56.1 | −2.26 |
| All HVs | 19.9 | 19.8 | 11.8 | 6.2 | −47.1 | −1.75 |

Sources: CBCS (1973), ABS (2008) and BITRE estimates.

vehicle loads and average vehicle utilisation to overall productivity growth. The next chapter outlines the factors that have contributed to road freight productivity growth.

CHAPTER 3

# Sources of heavy vehicle productivity growth

## Key points

- This chapter outlines the main factors that have contributed to growth in heavy vehicle productivity over the last three and a half decades.
- The gradual increase in the share of freight carried by larger heavy vehicle configurations accounts for around 80 per cent of the growth in fleet-wide average loads.
- The introduction of new, larger heavy vehicle combinations—six-axle articulated trucks in the 1970s and B-doubles in the 1990s—contributed significantly to the growth in road freight productivity. These two vehicle combinations presently account for over 70 per cent of all road freight movements.
- Other factors contributing to growth in heavy vehicle freight shares include cost—the average cost per tonne kilometre is generally lower for larger heavy vehicle configurations—and strong growth in long distance road freight and cumulative non-urban road infrastructure investment since the 1970s.
- Progressive increases in regulated mass and dimension limits for heavy vehicles, which have enabled existing vehicle classes to carry greater mass and higher volumes, are estimated to account for around 20 per cent of the increase in fleet-wide average loads.

## 3.1 Introduction

Chapter 2 described the strong growth in heavy vehicle productivity that has occurred over the last four decades, and provided some evidence to suggest that the availability of, and increased share of freight carried by, larger heavy vehicle combinations has contributed significantly to the increase in heavy vehicle productivity. This chapter explores in more detail the sources of heavy vehicle productivity growth, particularly the influence of heavy vehicle regulatory arrangements. The quantitative model described in Section 3.4 provides an explicit link between heavy vehicle productivity and cost and regulatory factors.

## 3.2 Heavy vehicle substitution and heavy vehicle productivity

Section 2.1 briefly highlighted trends in the share of freight carried by different commercial vehicle types over the last four decades. This section expands on that material, outlining trends in freight shares across ten different commercial vehicle classes, and illustrating the impact of freight vehicle substitution on heavy vehicle productivity growth. Throughout most of this chapter, discussion of freight vehicle productivity growth focusses mainly on increases in heavy vehicle average loads, which has accounted for more than half the increase in heavy freight vehicle productivity.

### *Heavy vehicle freight shares*

Figure 3.1 reproduces the heavy vehicle freight shares shown in Figure 2.2, but now distributed across ten different commercial vehicle categories:

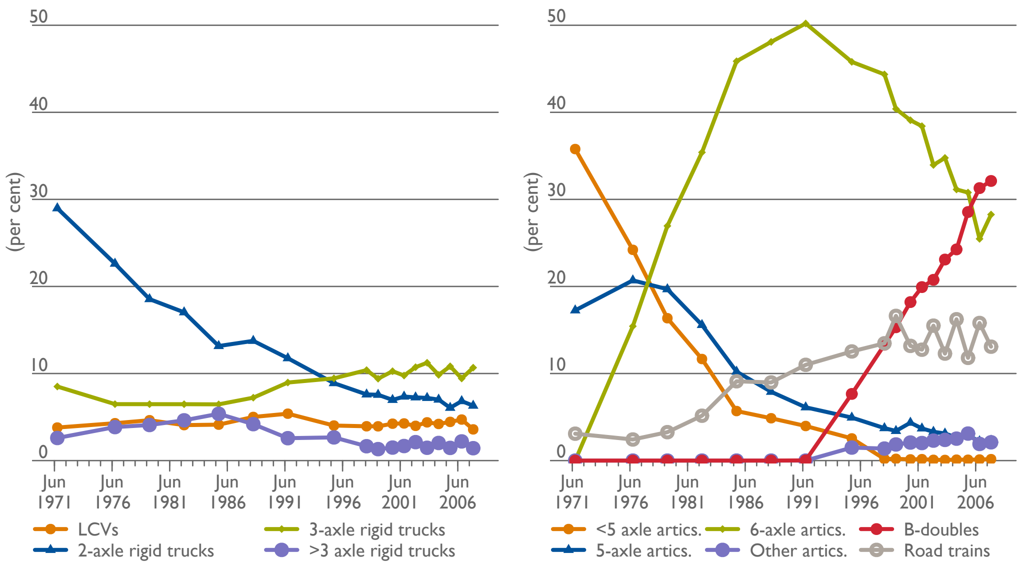
- LCVs
- Two-axle rigid trucks
- Three-axle rigid trucks
- Four-axle rigid trucks
- Less than five-axle articulated trucks
- Five-axle articulated trucks
- Six-axle articulated trucks
- B-doubles
- Road trains
- Other articulated trucks (not elsewhere specified)

These ten categories represent the most disaggregated categorisation of freight vehicle activity since 1971 for which data is publicly available (ABS 2008, and earlier issues).

Figure 3.1 illustrates again the significance of six-axle articulated trucks and B-doubles to the overall road freight task. It also shows the impact that uptake of six-axle articulated trucks had on the share of freight carried by five-axle and less-than-five axle articulated trucks in the early 1970s. In particular, the share of freight carried by less-than-five axle articulated trucks declined from 35 per cent of total road freight in 1971 to less than 10 per cent of total road freight by 1985, and has since declined to negligible levels. The share of freight carried by five-axle articulated trucks increased between 1971 and 1976, but following the introduction and widespread uptake of six-axle articulated trucks the share of freight carried by five-axle articulated trucks has declined.

Figure 3.1 also shows the share of freight carried by two-axle rigid trucks has declined from around 30 per cent in 1971 to less than 10 per cent in 2007. The share of freight carried by three-axle rigid trucks has increased slightly over the entire period, to around 10 per cent of total freight in 2007, with most of the increase in share having occurred since the mid-1980s. The share of freight carried by four-axle rigid trucks increased to around 6 per cent of total freight in 1985, but has declined to generally less than 3 per cent of total freight.

F3.1 Road freight shares by vehicle type and vehicle axle configuration, 1971–2007




Note: SMVU reported 'Other articulated trucks' include low-loaders and greater than three-trailer road trains.
Sources: ABS (2008, and earlier issues) and BITRE estimates.

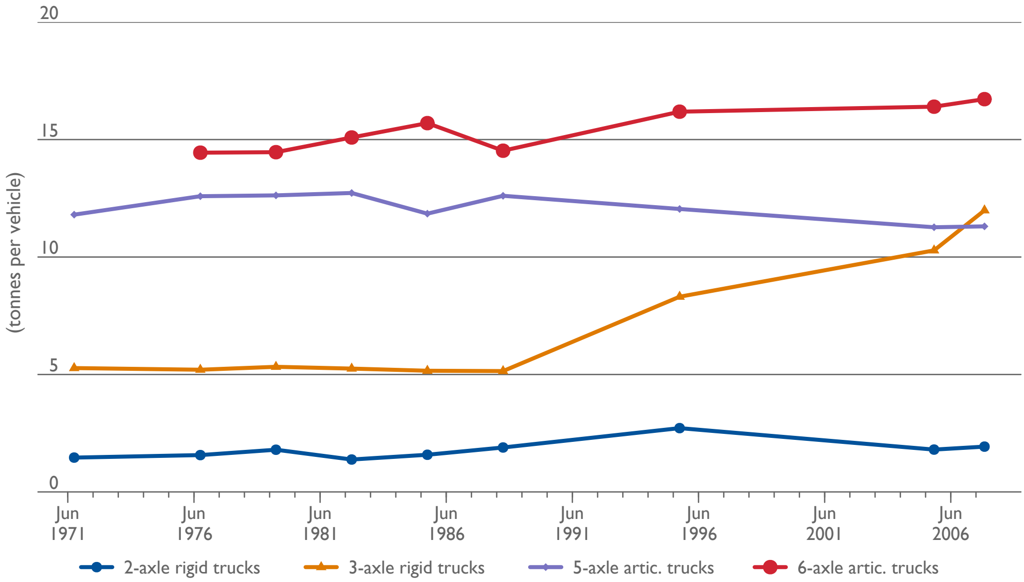
## *Heavy vehicle freight shares and average loads*

The average load within each of the ten freight vehicle classes has generally changed only marginally over the last 30 years. Figure 3.2 shows the trend average load for LCVs, two- and three-axle rigid trucks and five- and six-axle articulated trucks. For all but three-axle rigid trucks, the within-class average load of freight vehicles has changed only modestly. Six-axle articulated truck average loads have increased approximately 15 per cent since 1976. The data implies that five-axle articulated truck average loads have actually decreased slightly since 1976. Two-axle rigid truck average loads have increased 23 per cent since 1976. The data also implies that three-axle rigid truck average loads have increased by over 100 per cent since 1976, partly fuelled by increasing use of three-axle rigid truck and trailer combination vehicles.

Consequently, growth in the share of freight carried by larger freight vehicles appears to account for most of the change in fleet-wide average loads for rigid and, most especially, articulated trucks. Figure 3.3 shows actual average loads (tonnes per vehicle kilometre) for rigid and articulated trucks, since 1972, and predicted average loads, derived by multiplying freight shares for the nine rigid and articulated truck classes in Figure 3.1 by the within-class average load for each vehicle class, assuming that within class average loads have varied only in line with in legislated increases in vehicle mass and dimension limits since 1971. The within-class average vehicle loads assumed for 2007 are listed in Table 3.1. (Appendix C outlines the method used to predict fleet-wide average loads.) The predicted fleet-wide average loads match actual average loads reasonably well over most of the sample period.

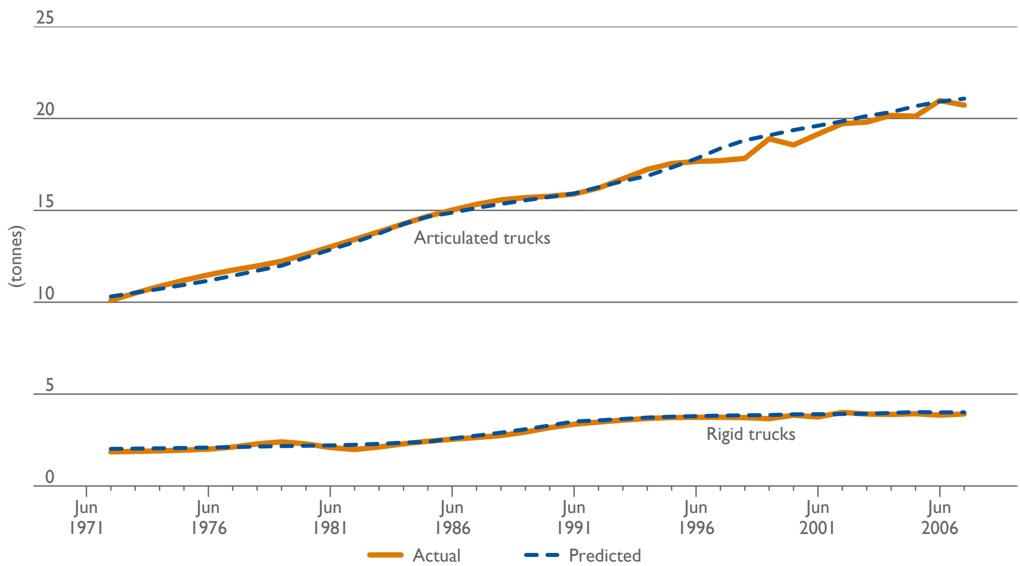
This method also enables estimation of the relative contribution of vehicle freight share trends and mass and dimension limit increases on fleet-wide productivity (average load) growth. The estimates imply that vehicle freight share trends account for over 80 per cent of the growth in average loads across all articulated trucks, and the remaining approximately 20 per cent is

## F3.2 Average load, selected freight vehicle classes, 1971–2007




Sources: ABS (2008, and earlier issues), NTC (2007a) and BITRE estimates.

## F3.3 Actual and predicted heavy vehicle average loads, 1972–2007




Source: BITRE estimates.

attributable to increased vehicle mass and dimension limits.

For rigid trucks, the story is reversed. Changes in the share of freight carried by two-, three- and four-axle rigid trucks appear to have only a minor impact on fleet-wide rigid truck average loads. Most of the measured increase in fleet-wide rigid truck average loads over the last forty years occurred between 1976 and 1994, and appears to be mainly attributable to increases in average loads of three-axle rigid trucks. Prior to 1976 and post-1994, the statistics imply there has been no significant change in fleet-wide rigid truck average loads.

T3.1 Assumed average loads, by vehicle type and axle configuration, 2007

| Rigid trucks | | Articulated trucks | |
|---|---|---|---|
| No. axles / vehicle type | Average load (tonnes) | No.axles / vehicle type | Average load (tonnes) |
| Two-axle | 2.5 | Less-than-five axle | 10.4 |
| Three-axle | 5.8 | Five axle | 12.9 |
| Four-axle | 6.9 | Six axle | 16.5 |
| | | B-doubles | 24.0 |
| | | Road trains | 33.0 |
| | | Other | 22.0 |

Source: NTC (2007a).

## *Evidence from WIM data*

Weigh-in-motion (WIM) data provides another source of information with which to gauge trends in road freight shares and road freight vehicle average loads. WIM data is not directly comparable with the SMVU-based data used throughout the rest of this report due to differences in vehicle classification and scope (or coverage).

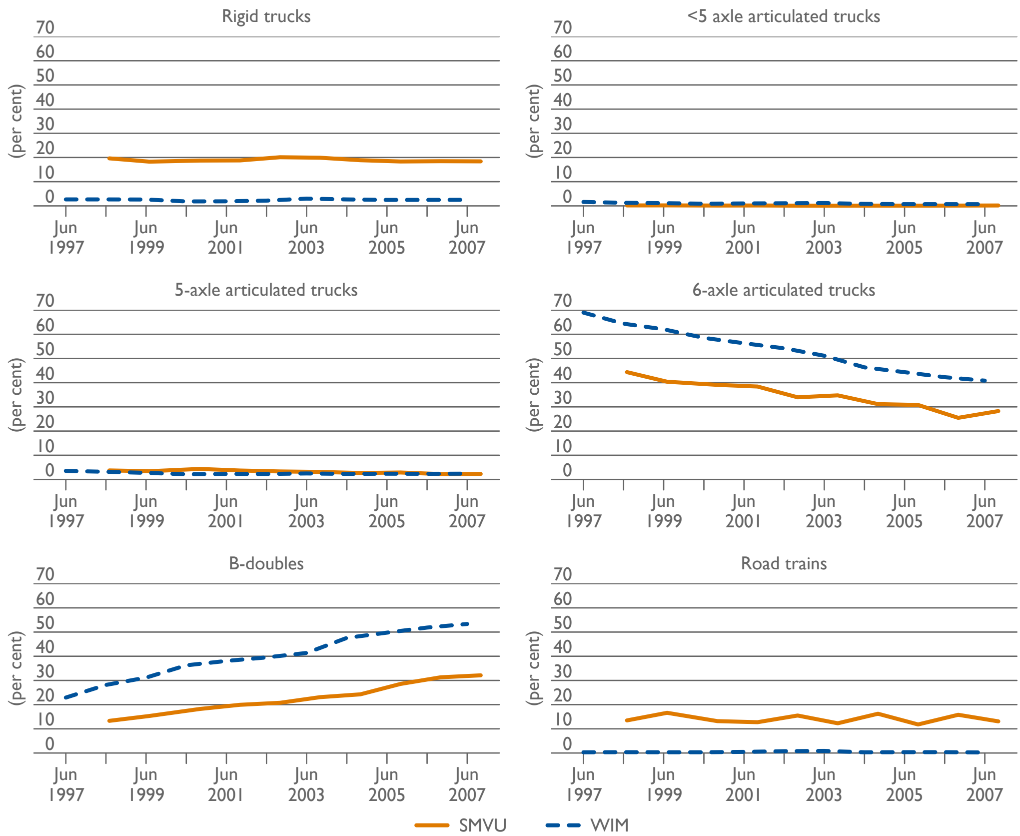
WIM equipment classifies vehicles according to number of axles and axle spacing and classified WIM data is reported by Austroads vehicle class.[4] Consequently, rigid trucks towing trailers are grouped with articulated trucks. For example, under the Austroads vehicle classification, three-axle rigid trucks towing a trailer could appear under classes 8, 9 or 10, depending on the number of axles on the trailer. (Throughout the rest of this report, three-axle rigid trucks towing a trailer are grouped with all other three-axle rigid trucks.)

WIM sites operated by State and Territory jurisdictions are predominantly located on major rural highways where larger heavy vehicles are a much greater share of total freight vehicle traffic. There are few WIM sites in urban areas, where rigid trucks are a larger share of total commercial vehicle traffic, and very few on local government roads. Only a few of the rural WIM sites cover road train accessible routes. The SMVU freight data, by contrast, covers freight vehicle activity across all parts of the road network. Consequently, WIM data will tend to show that larger heavy vehicles comprise a much greater share of total heavy vehicle movements and freight in comparison to the SMVU data. Reported average loads are also likely to differ across the two data sets. Nonetheless, comparing the trends across the two data sets is instructive.

Figure 3.4 provides a comparison of trends in SMVU and WIM-site based heavy vehicle freight shares between 1995 and 2007. The WIM-site estimates are derived from aggregate data provided by state and territory road authorities from 1995 onwards. The WIM data covers all WIM sites in New South Wales, Victoria, Queensland, South Australia and Northern Territory (from 1998 onwards). Annual data for Western Australia and Tasmania is not included.[5] While the

4 Refer to Appendix A for illustration of Austroads vehicle classification.
5 Tasmania has recently revamped its WIM freight network and reliable data is only available for 2008. Western Australia WIM data was only available for a few years within the full observation period. The Australian Capital Territory (ACT) does not operate WIM sites.

F3.4 Comparison of SMVU and WIM-based freight shares, 1997 to 2007



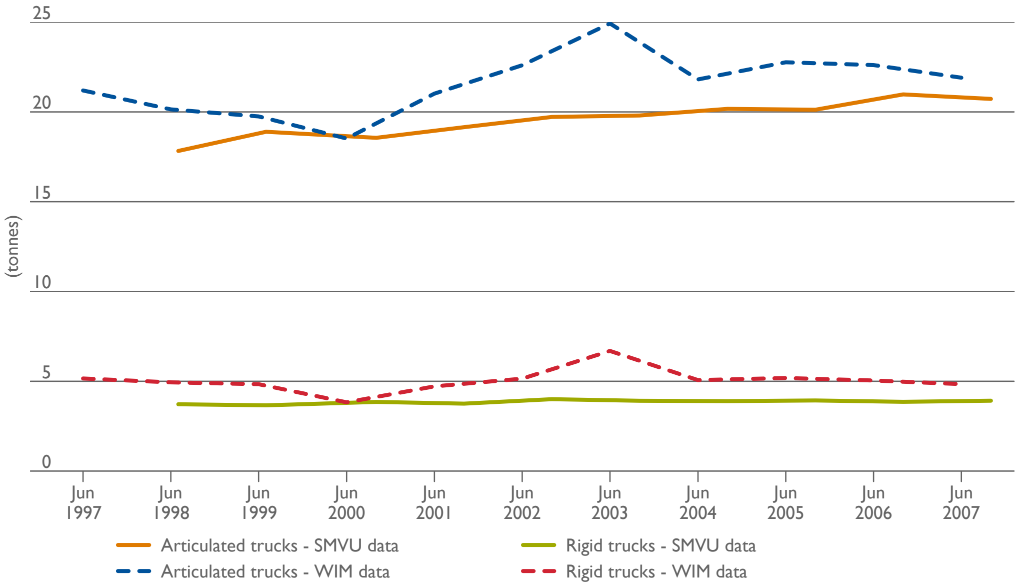

Sources: ABS (2008, and earlier issues), State and Territory WIM data and BITRE estimates.

absolute share of freight, as expected, differs substantially between the SMVU and WIM data across different vehicle categories, the comparison does show similar freight share trends—strong growth in the share of freight carried by B-doubles since 1995 and a decline in the share of freight carried by six-axle articulated trucks. (The WIM data implies that five-axle and less-than-five axle articulated trucks are a negligible share of rural freight volumes.)

Figure 3.5 shows the estimated average loads for rigid and articulated trucks between 1995 and 2007 for the SMVU and WIM data. As expected, differences between SMVU and WIM-site share of freight carried by different vehicle types, due to differences in network coverage, mean that estimated average loads differ using the two measures. Nonetheless, the two data sources exhibit similar trends—a slight increase in articulated truck average loads since 1995 and more or less unchanged rigid truck average loads. If anything, the WIM-based data shows articulated truck average loads have grown faster than the SMVU-estimated average loads, which may reflect the higher share and faster growth of B-double freight on rural highway links.

WIM site data also provides information on trends in class average loads, albeit by Austroads vehicle class, and so provides some more evidence on the relative contribution of growth in individual vehicle loads and changes in freight share on overall average loads. Figure 3.6 shows the growth in average vehicle loads, between 1995 and 2007, for six aggregated vehicle classes:

F3.5 Comparison of SMVU and WIM-based average loads, 1995 to 2007




Sources: ABS (2008, and earlier issues), State and Territory WIM data and BITRE estimates.

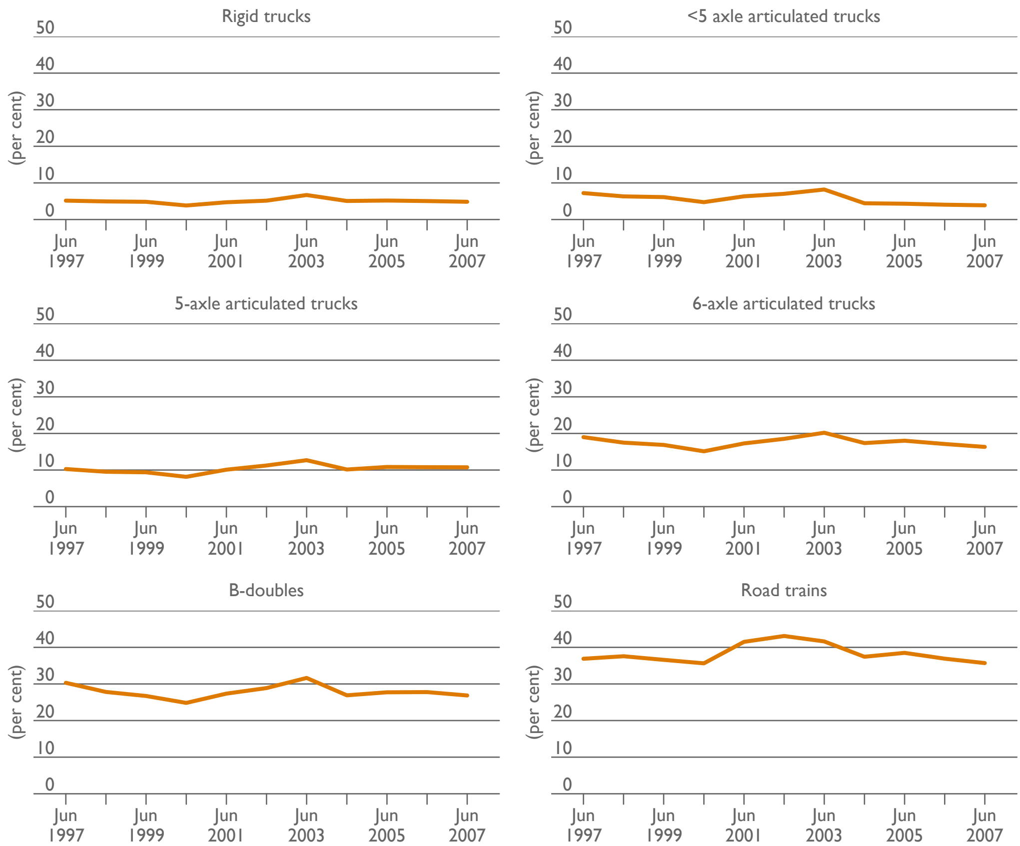
- rigid trucks
- less-than-five axle articulated trucks
- five-axle articulated trucks
- six-axle articulated trucks
- B-doubles
- road trains.

It is notable that, around annual variation in measured average loads, the WIM data exhibits little change in within-class average vehicle loads over this period. The implication is that, at least for rural and long-distance road freight, any increase in fleet-wide average loads across all articulated trucks will be mostly attributable to changes in the share of freight carried by different vehicle classes.

Freight vehicles are also responsible for nearly all of vehicle-induced road wear. The impact of vehicles on pavements is generally measured in terms of the number equivalent standard axles (ESAs).[6] WIM technology also calculates the ESA load of each heavy vehicle. Generally, the larger the vehicle the higher the average ESAs. For example, six-axle articulated trucks carrying 18 tonnes payload (near national average payload) produce approximately 2.3 ESAs, while a nine-axle B-double carrying 28 tonnes payload produce 3.5 ESA. However, larger freight vehicles generally produce fewer ESAs per tonne of freight. Figure 3.7, for example, plots the average ESAs per tonne of freight by broad vehicle type from selected WIM sites between 1997 and 2009. Ignoring the year-to-year variation (especially the above average estimates in 2003) the figure shows that average ESAs per freight tonne are generally inversely related to vehicle

6 One ESA is the equivalent road wearing effect of 80kN (8164kg) on a single axle.

F3.6 WIM-site average vehicle loads, by Austroads vehicle class, 1995 to 2007

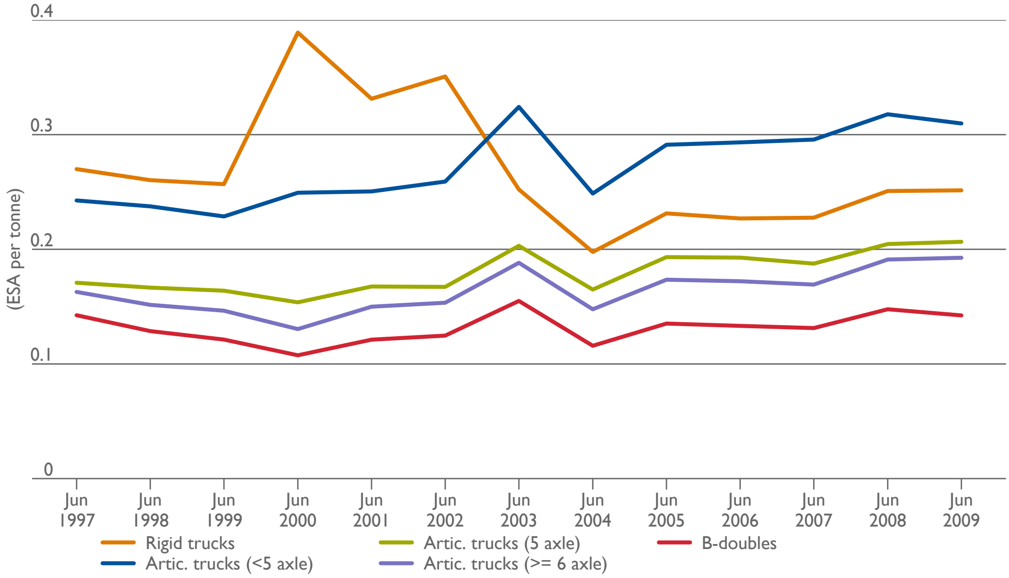



Sources: State and Territory WIM data and BITRE estimates.

size—that is, average ESAs per tonne for a B-double is approximately 20 per cent lower than that of a six-axle articulated truck, which is, in turn, approximately 15 per cent below that of a five-axle articulated truck. All vehicle combinations exhibit a slight increase in average ESAs per tonne over the 12 years to 2009.

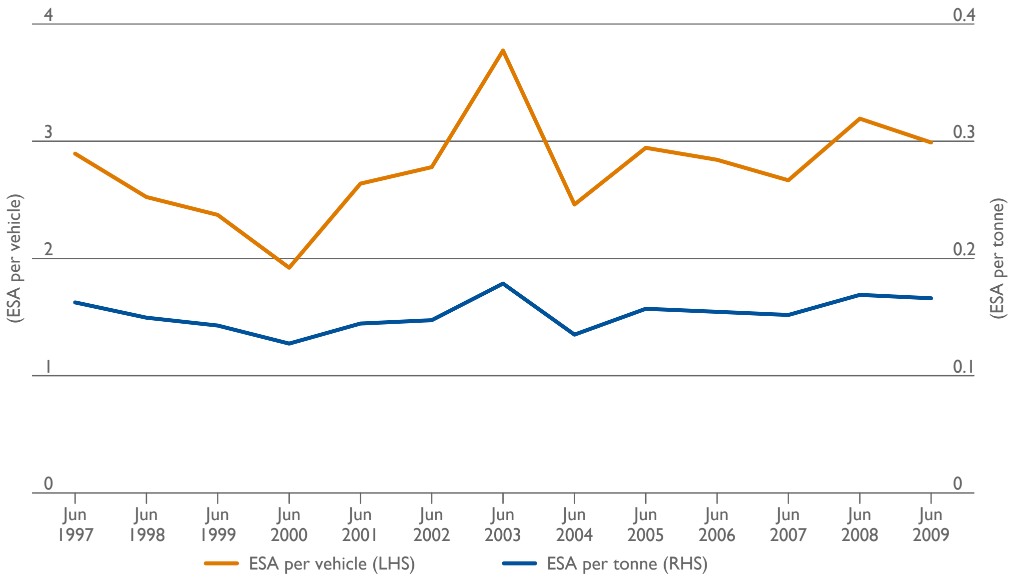
The overall road wearing impact of changes in commercial vehicle freight shares is illustrated in Figure 3.8. It shows the average ESAs per freight vehicle and per tonne of freight moved, for selected WIM sites, between 1997 and 2009. Average ESAs per vehicle exhibit significant variation over this period, but have generally averaged around 3 ESAs per vehicle since 2002. Average ESAs per tonne of freight has generally averaged around 0.16 ESAs per tonne, with the increase in freight share carried by larger vehicle combinations, particularly B-doubles, offsetting the measured increase in within-class average ESAs per tonne. The implication of these results is that the transfer of freight to larger heavy vehicle combinations has a neutral to marginally benign impact on road pavements.

F3.7 Average ESAs per tonne of freight, by broad commercial vehicle type




Sources: State and Territory WIM data and BITRE estimates.

F3.8 Average ESAs per vehicle and per tonne of freight




Sources: State and Territory WIM data and BITRE estimates.

## 3.3 Factors affecting heavy vehicle freight shares

Heavy vehicle regulatory reform has arguably been a significant driver of improvements in heavy vehicle productivity. Increased mass and dimension limits, the introduction of more productive heavy vehicle classes, harmonisation of driving hours, changes in heavy vehicle highway speed limits, and the removal of State-based economic regulation of road freight have all contributed to the growth in road freight and heavy vehicle productivity over the last 35 years. This section outlines the major heavy vehicle regulatory reforms that have occurred since 1971.

## *Vehicle mass and dimension limits*

Regulations governing the maximum mass and dimensions (length, width and height) of heavy vehicles have historically been set to limit the road wear impact of heavy vehicle road use and minimise the safety impact of heavy vehicle road use.

In principle, there will be an optimal level for heavy vehicle mass and dimension limits—where the benefits of improved freight productivity from increasing limits exactly offset the additional road wear and safety impact. Such *optimal* mass limits would vary not only by heavy vehicle class, but also by road standard—that is, assuming no difference in productivity benefits across roads, the optimal mass limits for higher standard roads would be above that for lower standard roads. Although there are instances where mass limits vary across different parts of the road network, either to limit excessive damage to some roads at certain times or allow higher mass vehicles to operate limited services for specified periods, for administrative simplicity, compliance and enforcement, mandated mass and dimension limits have generally been applied across the network. Other local mass and dimension limit variations include requiring B-doubles to be split before traversing certain bridges and limits on night-time travel through some towns.

Heavy vehicle mass and dimension limits are governed by state and territory legislation. Up until 1995 mass and dimension limits were set independently by each jurisdictions and, consequently, there were differences in mandated limits across jurisdictions. Since 1996 national uniform heavy vehicle mass and dimension limits have applied, set through state/territory legislation based on national model legislation.

Progressive relaxation of regulations governing general vehicle mass and dimension over the past thirty years has facilitated the use of larger heavy vehicles across the road network. This has involved both progressively expanding road access for particular vehicle configurations and increasing dimension limits for individual vehicle classes.

### Mass limits regulation

Since 1971, there have been six major revisions to heavy vehicle mass limits:

- Implementation of *Economics of Road Vehicle Limits* (ERVL) study (NAASRA 1976) mass and dimension limit recommendations (in all jurisdictions but South Australia and Australian Capital Territory) in 1979–80.
- National agreement to implement the *Review of Road Vehicle Limits* (RoRVL) study (NAASRA 1985) mass and dimension limit recommendations in 1986.[7] New South Wales and Victoria later agreed (September 1987) to implement RoRVL Option A (i.e. gross mass limit of 41.0 tonnes for six-axle articulated trucks) (NAASRA 1985, p. 1).
- Introduction and adoption, by all states and territories, of uniform national heavy vehicle mass and dimension limits legislation and regulations introduced between 1993 and 1995.[8]

7 Gross mass limits – 38.0 tonnes in New South Wales and Victoria; 41.0 tonnes in Queensland and Tasmania; and 42.5 tonnes in South Australia, Western Australia and Northern Territory.

8 *Road Transport Reform (Vehicles and Traffic) Act 1993* and *Road Transport Reform (Mass and Loading) Regulations*.

- Australian Transport Council (ATC) approval of the Higher Mass Limits (HML) reform package in 1998.
- Introduction of Concessional Mass Limits (CML) reforms in 2006.
- ATC approval of Performance Based Standards (PBS) heavy vehicle regulatory reforms in 2007.

Figures 3.9 and 3.10 illustrate the impact of increases in regulated heavy vehicle mass limits for rigid and articulated trucks, respectively, between 1971 and 2010. The solid lines indicate GML limits applying to different rigid and articulated truck configurations. The dashed lines indicate the mass limits applying to HML vehicles—that is, vehicles fitted with road friendly suspensions that meet specified damping and load sharing requirements—from 1998. The pre-1995 mass limit estimates pre-date the adoption of national uniform mass limits in the mid-1990s and are an approximate freight weighted-average of separate state/territory regulated mass limits.

As a result of changes in mass limit regulations, the maximum allowable mass of rigid and articulated trucks operating under GML has increased by between 12 and 27 per cent, across different vehicle types, since 1971. Incorporating HML, progressive increases in regulated mass limits have increased the maximum allowable mass for rigid and articulated trucks by between 14 and 33 per cent since 1971.

In particular, the maximum allowable mass of six-axle articulated trucks operating under GML has increased by around 27 per cent over that period. Including HML-compliant vehicles, the maximum allowable mass of six-axle articulated trucks has increased by 33 per cent. The maximum allowable mass of five-axle articulated trucks has increased 24 per cent since 1971. The maximum allowable mass for rigid trucks, without trailers, has increased 16 per cent for two-axle rigid trucks, 24 per cent for three-axle rigid trucks and 14 per cent for four-axle rigid trucks. Road train mass limits varied significantly across the different jurisdictions prior to the adoption of uniform national mass limits in the mid-1990s. Consequently, since 1971, GML for road trains in Western Australia and the Northern Territory have increased by around 9 per cent, but by 60 per cent in Queensland and South Australia.

## Dimension limits regulation

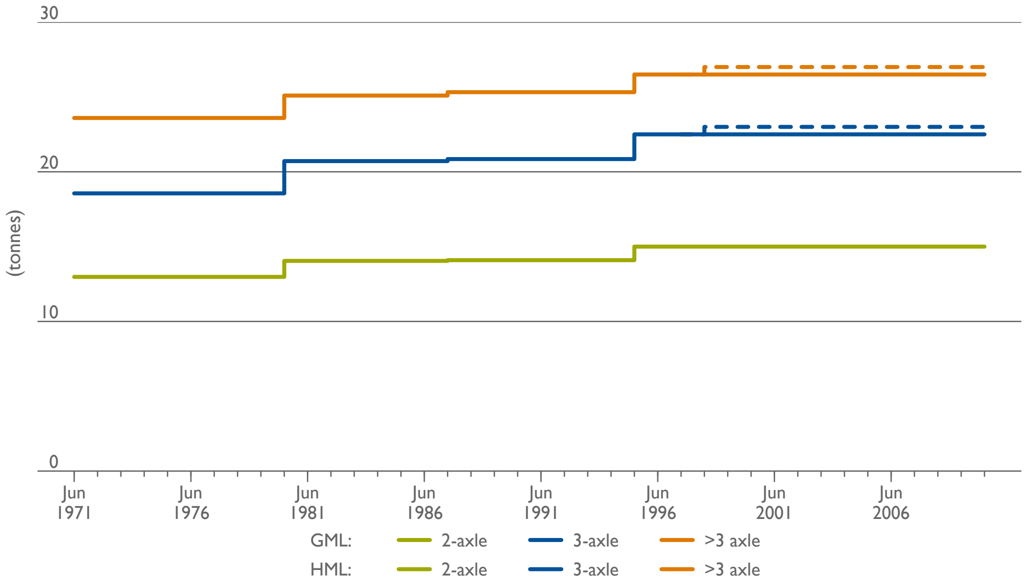
Vehicle length, width and height influence the volumetric freight capacity of heavy vehicles—larger dimension vehicles provide more volumetric freight carrying capacity and reduce the average cost of freight. For lower density freight cargoes, volumetric capacity is often more significant than mass limits. The length of heavy vehicles affects the distance and time required by faster vehicles to overtake a heavy vehicle, and so impacts on road safety, particularly on undivided carriageways.

Regulated heavy vehicle dimension limits have also increased since 1971, generally in concert with increases in vehicle mass limits. There have been five major changes in heavy vehicle length limits since 1971. These are:

- Implementation of ERVL study (NAASRA 1976) dimension limit recommendations (in all jurisdictions but South Australia and Australian Capital Territory) in 1979–80.
- National agreement to implement the RoRVL study (NAASRA 1985) dimension limit recommendations.
- Uniform national heavy vehicle mass and dimension limits legislation and regulations introduced and adopted by all jurisdictions between 1993 and 1995.[9] The allowable length for

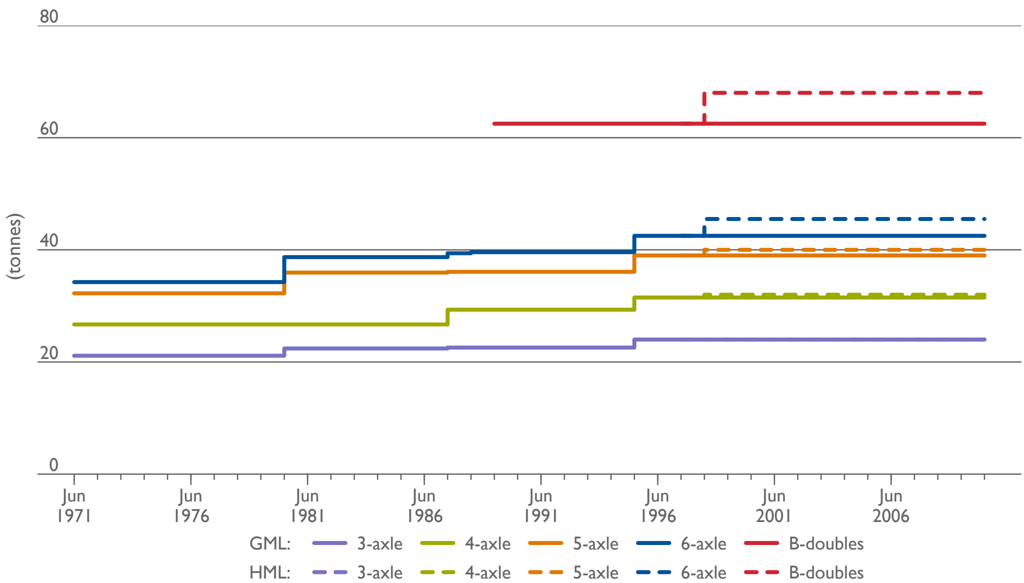
9 *Road Transport Reform (Vehicles and Traffic) Act 1993* and *Road Transport Reform (Mass and Loading) Regulations*.

## F3.9 Rigid truck mass limits, 1971–2010




Sources: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b), NTC (2008) and BITRE estimates.

## F3.10 Articulated truck mass limits, 1971–2010




Sources: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b), NTC (2008) and BITRE estimates.

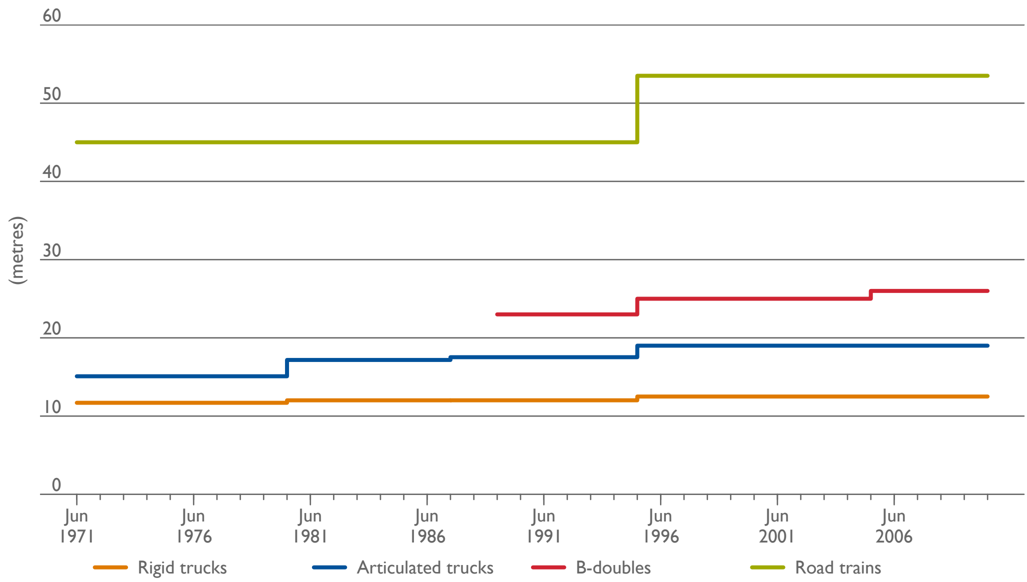
B-doubles was increased from 23 metres to 25 metres, complementing the increase in the mass limits.[10]

10 National length limits for multi-articulated vehicles are codified in *Australian Vehicle Standards Rule 69*.

- In 1997, the maximum allowable length for single semi-trailers (i.e. trailers towed by articulated trucks) increased from 13.7 metres to 14.6 metres.
- In 2005, the maximum allowable length of B-doubles was increased from 25 metres to 26 metres.[11].

Since 1971, regulated increases in the maximum allowable length of heavy freight vehicles has resulted in a 7 per cent increase in the maximum allowable length of rigid trucks and a 26 per cent increase in the maximum allowable length of single-trailer articulated trucks. Over the same period, the maximum allowable length of road trains has increased 19 per cent. Figure 3.11 illustrates the increase in regulated heavy vehicle dimension limits for rigid, single-trailer articulated trucks, B-doubles and road trains, between 1971 and 2010. Again, as for mass limits, the pre-1995 dimension limit estimates are an approximate freight-weighted average of separate state and territory regulated dimension limits.

F3.11 Heavy vehicle dimension limits, 1971–2010




Sources: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b), NTC (2008) and BITRE estimates.

## *Network access*

Heavy vehicle network access has also expanded significantly since 1971, particularly for road trains and B-doubles.

### Road trains

Road trains have been operating in Australia since the 1920s, largely in remote areas in South Australia, Western Australia and Northern Territory. Road trains remained confined largely

11 *Australian Vehicle Standards Rules 1999* and National Transport Commission (Road Transport Legislation – Vehicle Standards) Amendment Regulations 2006 (No. 2).

to highways in remote areas for many years. Since the early 1990's the road train network access has expanded significantly to include rural and remote highways in New South Wales and Queensland.[12] The current road train network includes all major roads between Adelaide and Perth, all major roads in the Northern Territory, most major roads in New South Wales (NSW) west of the Newell Highway, and all major roads in Queensland west of the Great Dividing Range.

### B-doubles

B-doubles were first trialled in Western Australia in the early 1980s. The original trial vehicles were introduced to more evenly distribute loads and reduce incidence of vehicle overloading while maintaining or improving on operational behaviour. The early trial B-doubles were based on the Canadian 'B-train' configuration (Pearson 2009). B-double vehicle trials soon followed in South Australia, Queensland, Victoria and New South Wales.

In 1985, following a review of B-double trial operations, Western Australia authorised the issue of permits for 18 metre B-doubles for transport of containers, bulk liquids and other commodities where weight variability was a problem. In 1987, Queensland approved permit operations of B-doubles on approved routes, subject to B-doubles satisfying NAASRA (1985) vehicle specification guidelines. In 1988, NSW approved interim guidelines for B-double operations, which notably featured no restrictions as to the type of goods that could by carried by B-doubles.

The first fully loaded B-double operated between Sydney and Melbourne in June 1991 and shortly thereafter the Victorian Government approved the issuance of permits for B-double use over a defined route network. Also in 1991, the Federal Transport Minister issued the first Federal Interstate Registration Scheme (FIRS) B-double permit (Pearson 2009).

Since then B-double road network access has been progressively and incrementally expanded. For example, it was not until August 2002, following upgrade of the Yelgun to Chinderah section of the Pacific Highway, that B-doubles were permitted access to the entire Pacific Highway in NSW, allowing uninterrupted use of B-doubles between Sydney and Brisbane for the first time. B-doubles are now permitted on all intercapital routes and on most major arterial roads within metropolitan areas.

## *Speed limits*

Until the mid-1980s, heavy vehicles were limited to 80 kilometres per hour outside built-up areas.[13] The 1984 *National Road Freight Industry Inquiry* report, identified speed limit differentials between light and heavy vehicles as a significant contributor to poor road safety outcomes—contributing to increased overtaking movements by light vehicles and increased accident risks. The *National Road Freight Industry Inquiry* report recommended removal of the light–heavy vehicle speed limit differential by raising heavy vehicle speed limits to existing light vehicle limits. In 1986, the Australian Transport Advisory Council (ATAC) adopted a trial maximum speed limit of 90 kilometres per hour for heavy vehicles. In December 1987, ATAC subsequently endorsed a maximum speed limit of 100 kilometres per hour for all heavy vehicles, except road trains, to apply from 1 July 1988. Road train vehicles remain limited to 90 kilometres per hour,[14] however, Western Australia and Northern Territory allow road trains to operate up to 100 kilometres per hour.

12 Non-livestock carrying road trains were not allowed in New South Wales prior to 1989.
13 Within built-up areas, heavy vehicles were subject to posted speed limits.
14 *Australian Vehicle Standards Rules 1999* (1999) stipulates the maximum speed limit of road train prime movers is 90 kilometres per hour.

## Driving hours regulations

Regulations governing heavy vehicle driving hours limit the number of hours a professional driver can drive without a break in a 24-hour period and over the course of a week. Prior to 1999, heavy vehicle driving hour regulations were set separately in each state and territory. The maximum continuous driving time without a rest break varied between 5.0 and 5.5 hours and the maximum number of driving hours in a 24-hour period varied between 11.0 and 12.0 hours.

In 1999, national model driving hours were adopted, to be implemented through state and territory legislation.[15] Current 'standard' driving hour regulations require drivers to take a 15-minute break in each 5.5 hour working period and limit driving to 12 hours in each 24-hour period. As of 2009, the national model legislation had been implemented in New South Wales, Victoria, Queensland and South Australia. Tasmania, Northern Territory and Australian Capital Territory had agreed but not yet implemented the legislation. Western Australian driving hour limits are governed under occupational health and safety legislation, and limits differ only slightly from the national model limits—the maximum continuous work time is 5 hours, with at least a 10 minute break for each five-hour work period and drivers are also expected to have had a 7-hour minimum continuous sleep break in the last 24 hours. While there remain some differences in implementation across jurisdictions, particularly how vehicle hours are counted, nominal driving hour limits are now broadly similar across Australia.

## Heavy vehicle road use charges

### Vehicle registration charges

Up until 1995, heavy vehicle registration charges, and variable road use charges, were set separately by each state and territory. Variation in registration charges prevailing across jurisdictions led to considerable shopping around by heavy vehicle operators.

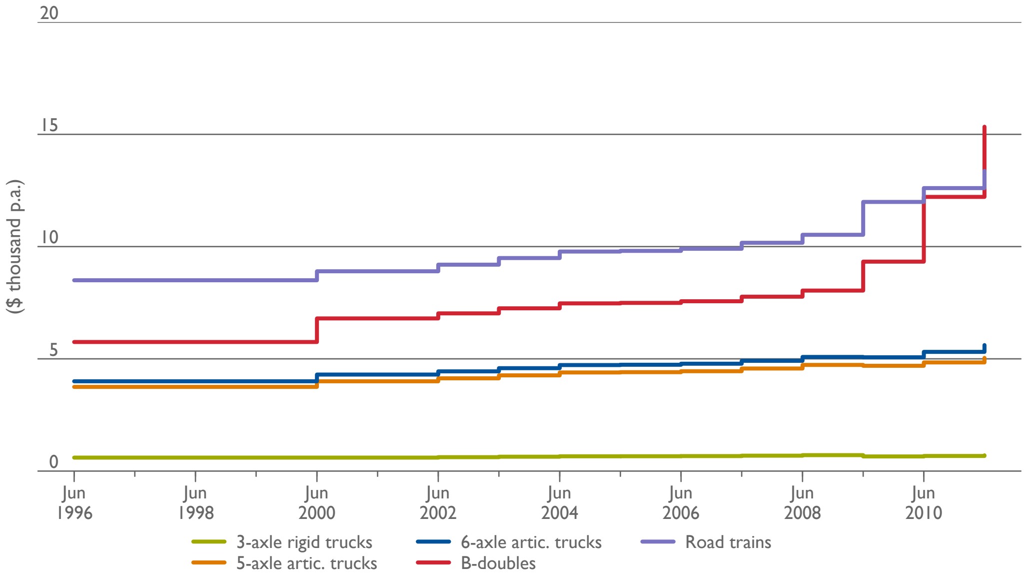
Nationally-uniform heavy vehicle charges, comprising a vehicle registration charge and notional fuel-based variable road use charge, were introduced in 1995. Between 2001 and 2006 heavy vehicle registration charges were revised annually, to reflect changes in road expenditure and road use, with the increase in charges capped to not exceed Consumer Price Index (CPI) growth in any one year. In response to a recommendation of the PC (2006) inquiry into road and rail freight infrastructure pricing, heavy vehicle registration and fuel-based road usage charges were revised in 2007 to ensure that heavy vehicles fully recovered their attributable costs both in total and by vehicle class. The revised charges resulted in significant increases in registration charges for B-doubles and road trains, to remove implied cross-subsidisation to these vehicle classes, to be phased in over three years (2008, 2009 and 2010). At the same time, the CPI cap was removed from the annual registration charge adjustment formula and the fuel-based charge was made explicit and indexed annually. Figure 3.12 illustrates nominal heavy vehicle registration charges applying to three-axle rigid trucks, five- and six-axle articulated trucks, B-doubles and triple road trains since 1996. Nominal registration charges for three-axle rigid trucks increased 17 per cent between 1996 and July 2010, five- and six-axle articulated truck

15 The model legislation provides three driver work/rest hours options:

1. standard hours for drivers (i.e. the standard work and rest times)
2. basic fatigue management (BFM) scheme hours
3. advanced fatigue management (AFM) scheme hours.

Most heavy vehicle drivers are expected to operate under standard hours.

F3.12 Nominal heavy vehicle registration charges, 1971–2009




Note: Increases in nominal B-double and road train vehicle registration charges between 2007 and 2010 reflect phased implementation of revised heavy vehicle charges in 2007, removing the implied cross-subsidy for those vehicle classes.
Sources: NRTC (1992), NRTC (1999), NTC (2006), NTC (2009a, and earlier issues) and BITRE estimates.

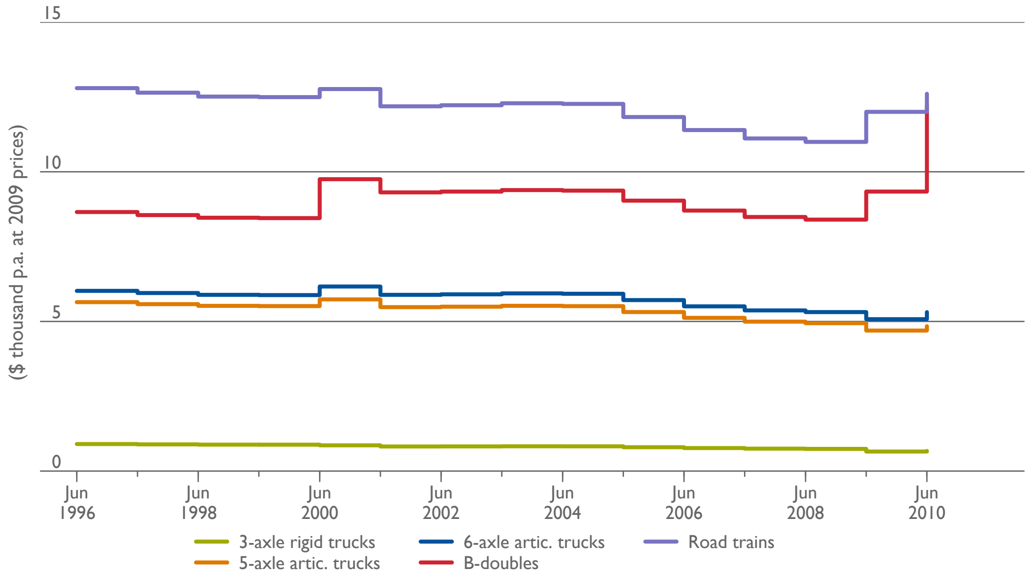
registration charges by approximately 35 per cent and 40 per cent, respectively, over the same period, triple road train registration charges by 57 per cent and B-double vehicle registration charges by 167 per cent. In real terms, relative to the GDP deflator, heavy vehicle registration charges for most vehicle classes have declined since 1996—three-axle rigid truck registration charges by approximately 25 per cent between 1996 and July 2010, five- and six-axle articulated truck registration charges by 12–14 per cent over the same period, and road train registration charges by 2 per cent. Only for B-doubles have real registration charges have increased, by 40 per cent since 1996, primarily as a result of recent revisions (see Figure 3.13).

Depending on average vehicle utilisation, heavy vehicle registration charges typically represent between 2 and 5 per cent of annual vehicle operating costs. Consequently, a 10 per cent increase in registration charges would increase overall operating costs by less than 0.5 per cent.

## *Road network improvements*

Enhancements to the road network since 1971, through investment in new infrastructure, upgrading road surfaces and duplication and realignment of the existing network, especially on the National Land Transport Network (NLTN) corridors, has been significant. These improvements have shortened travel times and lowered freight transport costs, especially for long-distance intercapital road freight, and contributed to growth in road freight. For example, investment in the Hume Highway, along with increases in heavy vehicle speed limits, has reduced heavy vehicle travel times between Sydney and Melbourne from around 15 hours in 1971 to around 11 hours today. Duplication of the remaining sections of the Hume Highway will further reduce travel times for inter-urban road freight on that corridor.

F3.13 Real heavy vehicle registration charges, 1971–2009




Note: Increases in real B-double and road train vehicle registration charges between 2007 and 2010 reflect phased implementation of revised heavy vehicle charges in 2007, removing the implied cross-subsidy for those vehicle classes.
Sources: NRTC (1992), NRTC (1999), NTC (2006), NTC (2009a, and earlier issues) and BITRE estimates.

## 3.4 Modelling trends in heavy vehicle freight shares

Given the importance of changes in the share of freight carried by different heavy vehicle classes to fleet-wide average loads and road freight vehicle productivity growth, modelling the impact of changes in vehicle operating costs and regulatory factors on freight vehicle type choice can help better inform policy. This section presents the results of a model that relates changes in heavy vehicle freight shares to transport costs and regulatory factors. (Appendix C provides more detail of the analytical methods and quantitative results.)

### *Model specification*

The Australian road freight industry is highly competitive. Market concentration is low—according to BTRE (2003) there were about 47 000 businesses operating in the hire and reward trucking sector in 2000, and the top 4 trucking firms accounted for only 15 per cent of total turnover—and relatively low start-up costs and readily transferable capital facilitate easy entry and exit. Consequently, there is considerable pressure on operators to minimise operating costs in providing freight services that match the needs of customers. In practice, this means that operators will choose that mix of vehicles and inputs that minimises costs subject to meeting the requirements of shippers (e.g. price, transit time, reliability, etc.) and freight characteristics (i.e. mass, volume, dimensions).

Aggregate vehicle type freight shares are modelled here as a function of vehicle operating costs and heavy vehicle regulatory factors, using a generalised extreme value (GEV) model specification. Costs enter the model as average variable vehicle operating costs per tonne kilometre. Costs per tonne kilometre equal average operating costs per vehicle kilometre divided by av-

## T3.2 Average heavy vehicle operating costs, 2007

| Vehicle type | Average vehicle operating cost | Average VKT | Average load | Average cost | |
|---|---|---|---|---|---|
| | *($ pa)* | *('000 km)* | *(tonnes)* | *(cents / km)* | *(cents / tkm)* |
| 2-axle rigid truck (4.5-7 tonnes, no trailer) | 22 100 | 15 284 | 1.3 | 144.6 | 111.2 |
| 3-axle rigid truck (over 18 tonnes, no trailer) | 37 400 | 27 567 | 6.2 | 135.7 | 21.9 |
| Heavy truck trailer (over 42.5 tonnes) | 116 200 | 73 983 | 15.5 | 157.1 | 10.1 |
| 6-axle articulated truck | 124 800 | 88 900 | 16.6 | 140.4 | 8.5 |
| 9-axle B-double | 278 200 | 178 988 | 26.5 | 155.4 | 5.9 |
| Double road train | 252 200 | 133 750 | 31.8 | 188.6 | 5.9 |
| Triple road train | 301 300 | 133 750 | 47.4 | 225.3 | 4.8 |

Source: NTC (2007b, Table ES2), NTC (2007a, Table 6, pp. 15–16) and BITRE estimates.

erage vehicle load carrying capacity. Operating costs included in the model are fuel, labour and vehicle registration charges. A lack of available data precluded inclusion of vehicle maintenance and (amortised) vehicle capital costs in the model. However, the model does include lagged share terms, to capture the lagged response of heavy vehicle operators to changes in vehicle operating and capital costs.

Average operating costs per vehicle kilometre are generally higher for larger vehicles. However, when vehicle freight carrying capacity is factored in, average operating costs per freight tonne kilometre (or capacity tonne kilometre) are generally lower for larger vehicle classes. Table 3.2 illustrates the general relationship between average heavy vehicle operating costs and vehicle size for seven selected heavy vehicle classes. For example, average per kilometre operating costs for nine-axle B-doubles are about 10 per cent higher than equivalent per kilometre operating costs for six-axle articulated trucks. However, the average per tonne kilometre operating cost of a B-double travelling 180 000 kilometres per year and carrying average mass is around 30 per cent lower than that of the average six-axle articulated truck.

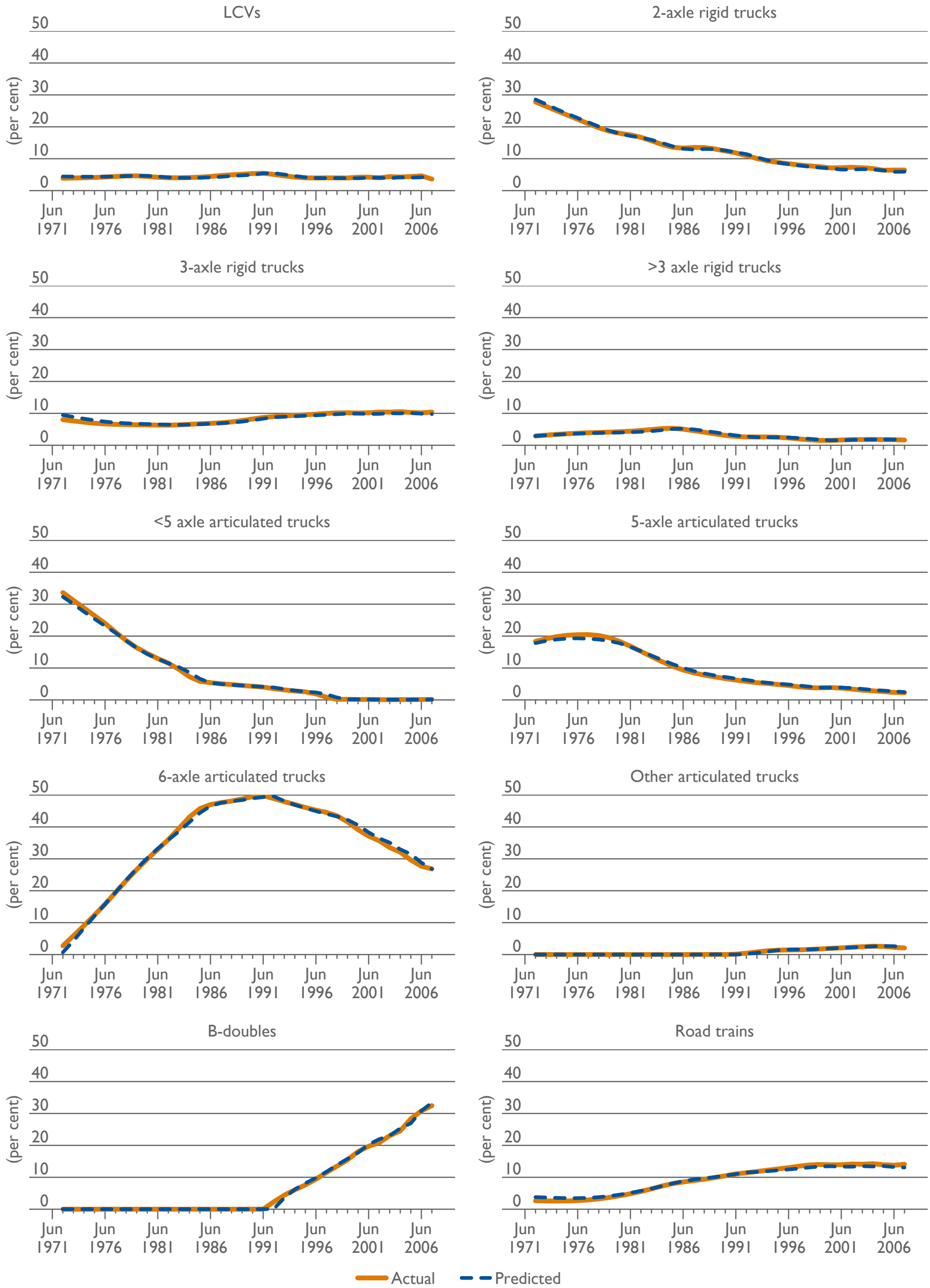
Regulatory factors enter the model both directly, through their impact on per kilometre average operating costs, and indirectly, through their impact on average vehicle load-carrying capacity. For example, changes in driving hours and maximum allowable vehicle speeds directly affect average labour costs. The capacity variable is a weighted linear sum of regulated mass (GML and HML) and dimension limits.

The GEV model is a general specification suitable for modelling market shares. The multinomial logit (MNL) model is the simplest and most widely known form of GEV model. Several different GEV specifications were estimated, including a MNL model, two nested logit specifications and a paired combinatorial logit (PCL) model. The results presented here are from the PCL model specification, which provided reasonable estimation results and while allowing a wider range of covariation between different vehicle classes than either the MNL and nested logit (NL) specifications. (Appendix C presents results for each of the different model specifications.)

Figure 3.14 shows the actual freight shares and model predictions by heavy vehicle type. It can be seen that the model provides relatively accurate predictions of freight shares for each of the 10 commercial vehicle types over the period 1972 to 2007. Only for the period following the widespread uptake of B-doubles, around 1991, does the model significantly under-predict aggregate freight shares, and then only for the first two to three years.

In turn, the predicted model shares can be used to predict fleet-wide average loads for rigid and articulated trucks. Figure 3.15 replicates the actual and predicted average loads for rigid and ar-

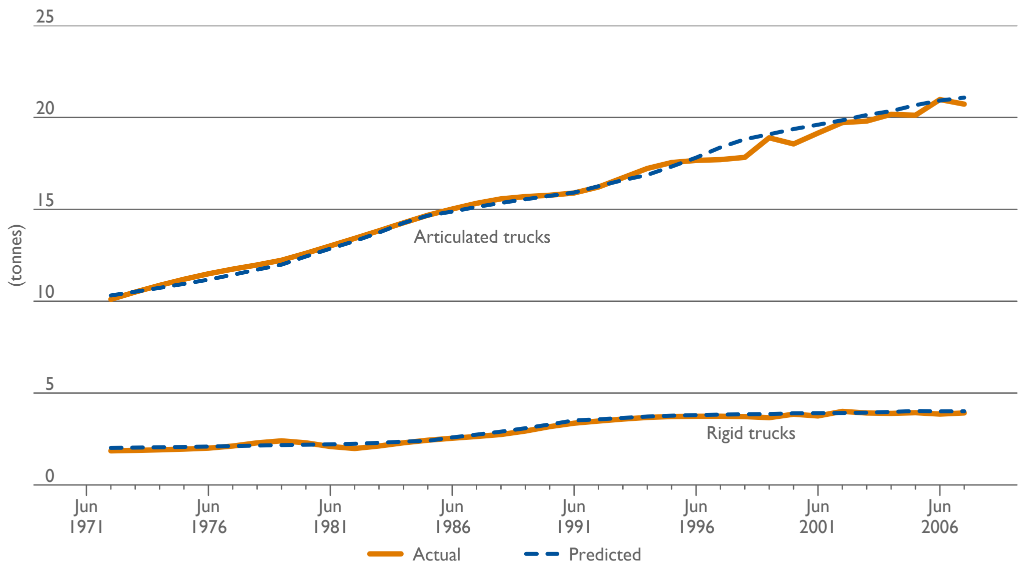
F3.14 Actual and predicted road freight shares, by vehicle type and axle configuration, 1972–2007




Source: BITRE estimates.

ticulated trucks shown in Figure 3.3 using the GEV model predicted vehicle freight shares instead of the actual vehicle freight shares. The figure shows that the freight share model predictions provide a good fit to historical trends in fleet-wide rigid and articulated truck average loads.

**F3.15** Actual and predicted heavy vehicle average loads, using GEV model predicted freight shares, 1972-2007




Source: Bureau of Infrastructure, Transport and Regional Economics (BITRE) estimates.

## *Impact of costs and regulatory factors on freight vehicle choice*

The incorporation of cost and regulatory factors in the freight share model provides a means of estimating the impact of changes in vehicle operating costs and regulatory factors on vehicle freight shares. The results can be used to provide quantitative estimates of the impact of potential future changes in these factors on vehicle type freight shares and, ultimately, truck productivity. The inclusion of lagged aggregate freight shares in the model allows delineation of short- and long-run effects.

Table 3.3 lists the long-run direct elasticity estimates with respect to average vehicle costs and regulated heavy vehicle mass and dimension limits—GML, HML and maximum length. The estimates imply that vehicle choice, at least in aggregate, is highly inelastic with respect to either cost and regulatory factors—in other words, a change in average vehicle operating costs has a very small impact on aggregate vehicle type choice and freight shares. The long-run cost elasticity estimates imply that a reduction in the average operating cost of any vehicle class will result in a small increase in the share of freight carried by that class. For example, the elasticity estimates imply that a 10 per cent reduction in B-double operating costs, in the absence of changes in the operating costs of other heavy vehicles, would increase B-doubles' aggregate share of total road freight by 0.6 per cent (or by 0.19 percentage points).[16] The GML and HML elasticities

16 The elasticities presented in Table 3.3 are the percentage change in market share. The absolute change in market share is derived by multiplying the percentage change in market share by the prevailing market share.

T3.3 Long-run direct elasticity estimates

| | | Regulatory factors | | |
|---|---|---|---|---|
| Vehicle type | Cost | GML | Max. Length | HML |
| LCVs | −0.1661 | 0.3775 | −0.2412 | 0.0298 |
| 2-axle rigid trucks | −0.0078 | 0.0126 | −0.0058 | 0.0010 |
| 3-axle rigid trucks | −0.0095 | 0.0124 | −0.0038 | 0.0010 |
| >3 axle axle rigid trucks | −0.0264 | 0.0322 | −0.0083 | 0.0026 |
| <5 axle articulated trucks | −0.0076 | 0.0101 | −0.0033 | 0.0008 |
| 5-axle articulated trucks | −0.0046 | 0.0056 | −0.0015 | 0.0004 |
| 6-axle articulated trucks | 0.0004 | −0.0004 | 0.0001 | 0.0000 |
| B-doubles | −0.0581 | 0.0694 | −0.0169 | 0.0057 |
| Road trains | −0.0095 | 0.0052 | −0.0011 | 0.0004 |
| Other articulated trucks | −0.0016 | 0.0020 | −0.0005 | 0.0002 |

Source: BITRE estimates.

imply that increases in the maximum allowable mass of any vehicle class will lead to a small increase in the share of freight carried by that vehicle class, which is as expected. The sign of the vehicle dimension variable implies, somewhat surprisingly, that increases in maximum allowable vehicle length dimension has a negative effect on vehicle freight shares. In other words, shorter heavy vehicles are generally preferred to longer vehicles. Nonetheless, the impact of this effect is again quite small. The impact of increases in vehicle dimension on heavy vehicle productivity will still be positive since the increase in freight capacity available from increased vehicle dimension outweighs any vehicle type freight share effect.

The long-run elasticities listed in Table 3.3 reflect the sustained or permanent impact of changes in costs and regulatory settings. The short-run elasticities, which are not shown here, are approximately an order of magnitude smaller than their long-run counterparts. In other words, the immediate impact of a changes in vehicle operating costs or regulated mass or dimension limits on vehicle type freight shares is near negligible.

## *Implications for freight shares and truck productivity*

The model results imply that, averaged across the Australian commercial vehicle fleet, marginal changes in vehicle operating costs and regulatory factors have only a very small impact on freight vehicle type choice. In effect, the model results suggest that operators already choose the most cost effective freight vehicle type suitable for their operations and that marginal changes in operating costs, or marginal changes in regulated vehicle limits, do not change the relative operating costs, or relative operating characteristics, between vehicle classes for most operators. In other words, a marginal reduction in six-axle articulated truck operating costs may reduce the difference in average operating costs between B-doubles and six-axle articulated trucks, however, B-double's will remain more cost effective, per tonne kilometre, in most applications. While data limitations precluded incorporation of other relevant factors, such as commodity and area of operation—e.g. urban, non-urban—the findings are likely to be similar for different commodities and in different geographic areas.

Consequently, it has been the introduction of new, larger heavy vehicle combinations—such as six-axle articulated trucks in the 1970s and B-doubles in the late 1980s—capable of carrying higher payloads and greater freight volumes, that has been the major driver of long-term trends in commercial vehicle freight shares, and fleet-wide average heavy vehicle productivity. Increases in regulated vehicle mass and dimension limits have also contributed to improvements in heavy vehicle productivity.

The next chapter considers possible future trends in heavy vehicle productivity.

CHAPTER 4

# Truck productivity: future prospects

## Key points

- This chapter presents estimates of potential future trends in fleet-wide rigid and articulated truck average loads using the model described in Chapter 3.
- The results imply that with no further productivity enhancing regulatory changes, there will be some continued growth in fleet-wide average vehicle loads into the future, as the share of freight carried by B-doubles continues to increase, but the rate of growth in fleet-wide average loads will be much less than previously.
- Increased uptake of higher productivity heavy vehicles available under PBS will boost fleet-wide average freight vehicle productivity. However, because these vehicles are limited to operating largely on rural and remote area roads they account for less than 20 per cent of all road freight and, consequently, their impact on overall freight vehicle productivity will be relatively small.
- If, however, B-triples could be used on B-double approved non-urban highways, the productivity benefits would be potentially greater. However, even under this scenario, while larger heavy vehicle combinations offer significant productivity benefits on these routes, across the entire heavy vehicle fleet the projected future growth in heavy vehicle average loads will be far less than growth experienced over the last 15 years.
- Of all the scenarios presented here, a uniform 10 per cent increase in mass limits would have the most significant impact on heavy vehicle productivity, potentially increasing fleet-wide average loads by up to 3 tonnes per vehicle kilometre.
- The implication of these scenarios is that we are near the limits of widespread productivity growth that can be extracted from marginal additional heavy vehicle regulatory reforms. With only modest future heavy vehicle regulatory reform productivity growth is likely to continue to occur but at a declining rate.

## 4.1 Introduction

The previous chapter outlined the major factors influencing trends in heavy vehicle productivity and presented the results of an empirical model relating road freight shares to changes in vehicle operating costs and regulatory settings. The model explains much of the observed variation in vehicle class specific road freight shares between 1971 and 2007. The chapter also demonstrated how changes in the share of freight carried by different heavy vehicle classes explain a large proportion of the observed growth in fleet-wide articulated truck average loads.

In this chapter, the model results presented in Chapter 3 are used to project likely future heavy vehicle freight shares, out to 2030, and the consequent implications for fleet average loads. Several scenarios are considered:

- A 'no further regulatory change' scenario
- A 'minimal PBS/Intelligent Access Program (IAP) network access' scenario—that is, use of B-triples, AB-triples and BAB-quad heavy vehicle types on road train routes
- An 'extended PBS/IAP network access' scenario—that is, B-triples operating on B-double routes and AB-triple, BAB-quad heavy vehicle types operating on road train routes.

The latter two scenarios are intended to illustrate the impact of PBS reforms on future heavy vehicle productivity. There are a wide range of larger heavy vehicle configurations available under PBS—including Super B-doubles, A-doubles and ABB-quads—and take-up will depend on the relative merits of these larger combinations in specific applications. Modelling all the possible vehicle combinations was beyond the scope of the model.

The chapter also presents results for two other scenarios run using the model described in Chapter 3. The first is a 'no B-doubles counterfactual' scenario, which estimates current heavy vehicle freight shares, fleet average loads and the size of the heavy vehicle fleet required to meet the current freight task had B-doubles not been introduced in the late 1980s. The second additional scenario models the impact of a uniform increase in GML, which estimates the future freight shares and fleet average loads were GML to be uniformly increased by ten per cent across all heavy vehicle classes. The model can also be used to estimate the impact of changes in costs on heavy vehicle freight shares and average loads. The chapter closes with a brief discussion of the modelled impact of recent revisions to B-double and road train registration charges.

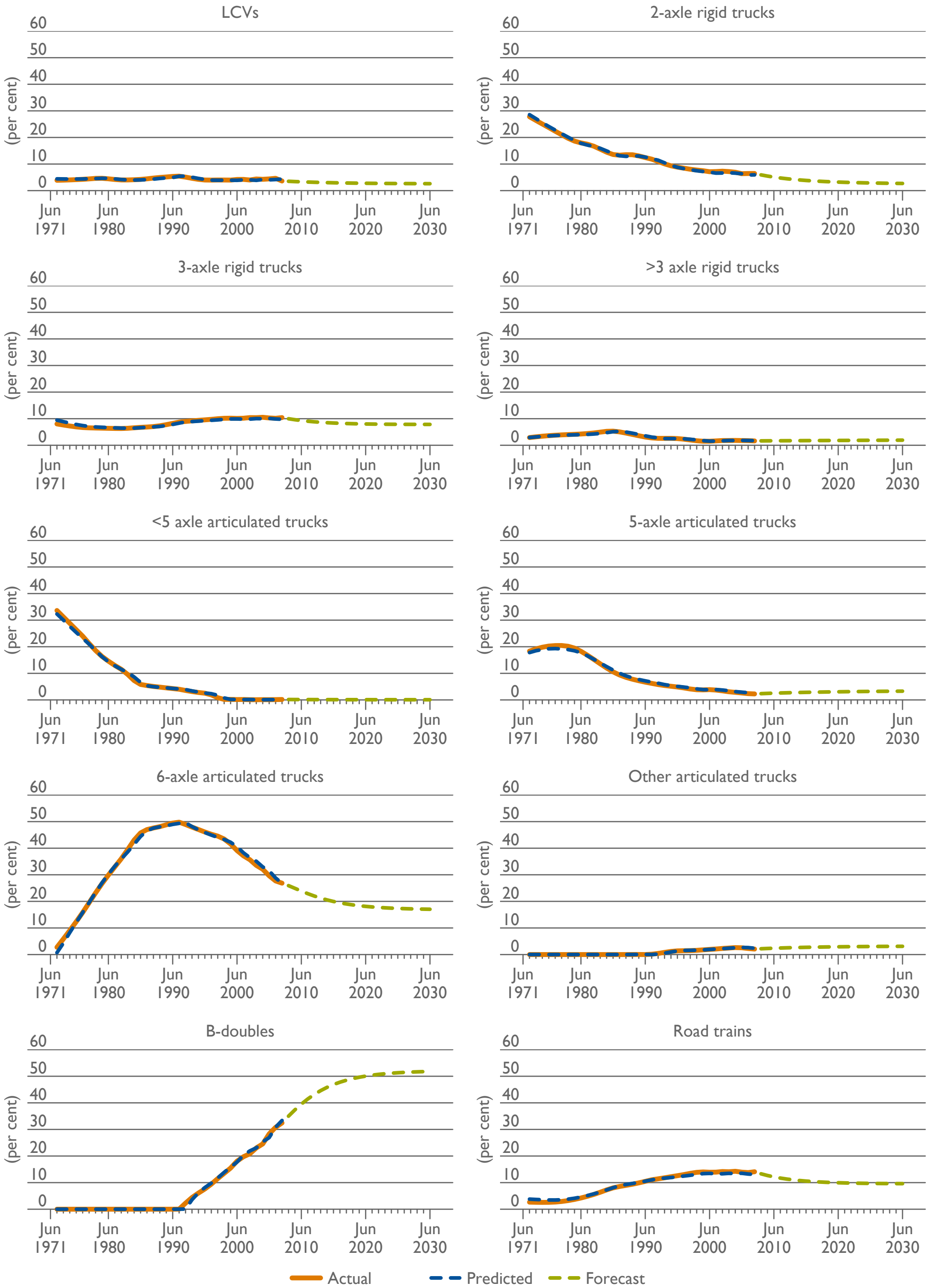
## 4.2 Potential future heavy vehicle productivity growth

### *No further regulatory change*

The 'no further regulatory change' scenario assumes there is no significant further change in heavy vehicle mass and dimension regulations between 2010 and 2030. Real heavy vehicle registration charges are assumed to remain at 2010 levels and average vehicle fuel efficiency (litres per vehicle kilometre) is assumed to improve by approximately 0.25 per cent per annum, across all heavy vehicle types. In addition, the uptake of PBS vehicles is assumed to remain relatively minimal.

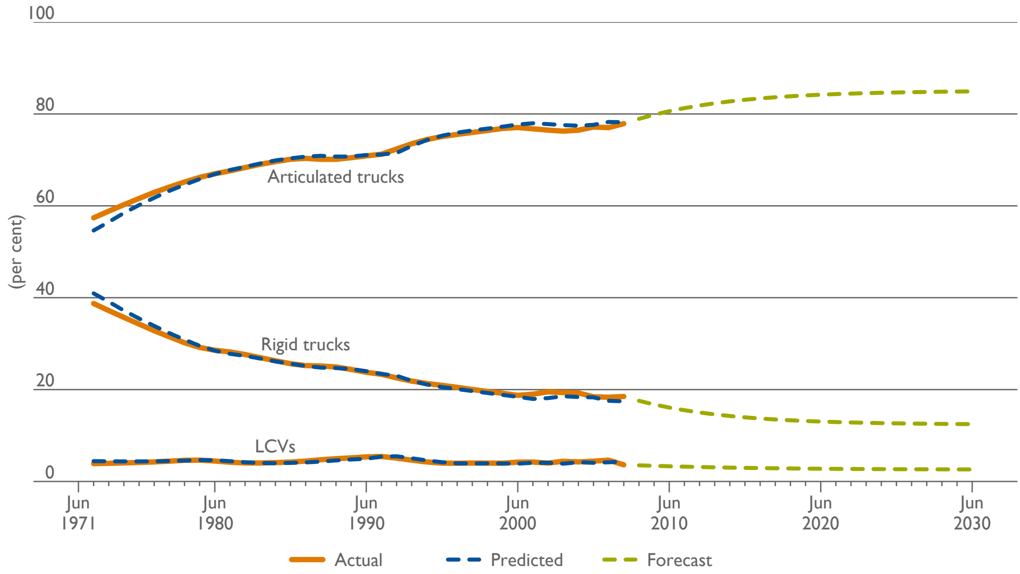
Under this scenario, the share of freight carried by B-doubles is projected to continue to increase, substituting for six-axle articulated trucks, such that, by 2030, B-doubles account for approximately 51 per cent of total road freight and six-axle articulated trucks 17 per cent. Road trains are projected to account for around 10 per cent of total freight and other articulated trucks between 2 and 3 per cent. Freight carried by all articulated trucks under this scenario is projected to increase to around 80 per cent of total road freight by 2030, rigid truck freight is projected to decline to 16 per cent of total road freight and LCVs are projected to continue to comprise between 3 and 4 per cent of total road freight. Figure 4.1 shows the detailed vehicle type freight share projections to 2030 and Figure 4.2 shows the projected freight shares aggregated by broad commercial vehicle class (i.e. LCVs, rigid trucks and articulated trucks).

F4.1 Actual and projected heavy vehicle freight shares, 1971–2030, no further reform scenario, by detailed commercial vehicle class



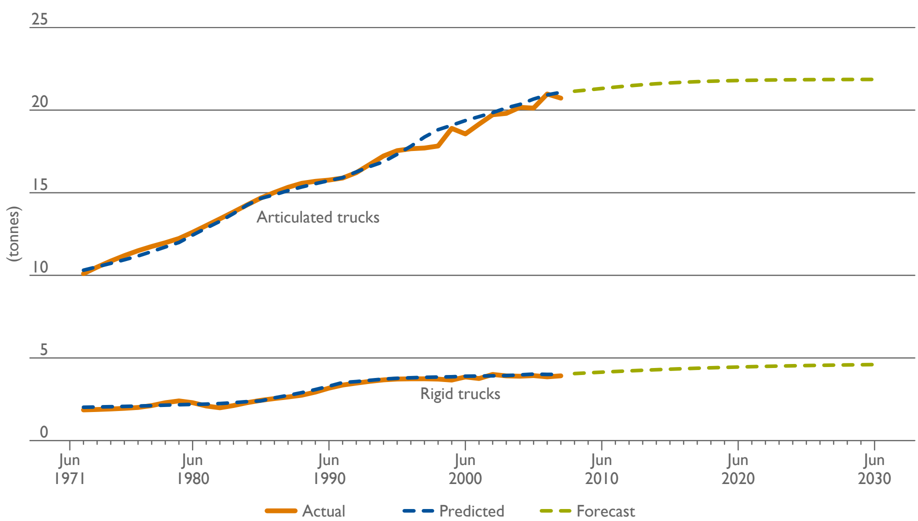

Source: BITRE estimates.

F4.2 Actual and projected heavy vehicle freight shares, 1971–2030, no further reform scenario, by broad commercial vehicle class




Source: BITRE estimates.

F4.3 Actual and projected average loads, 1971–2030, no further reform scenario




Source: BITRE estimates.

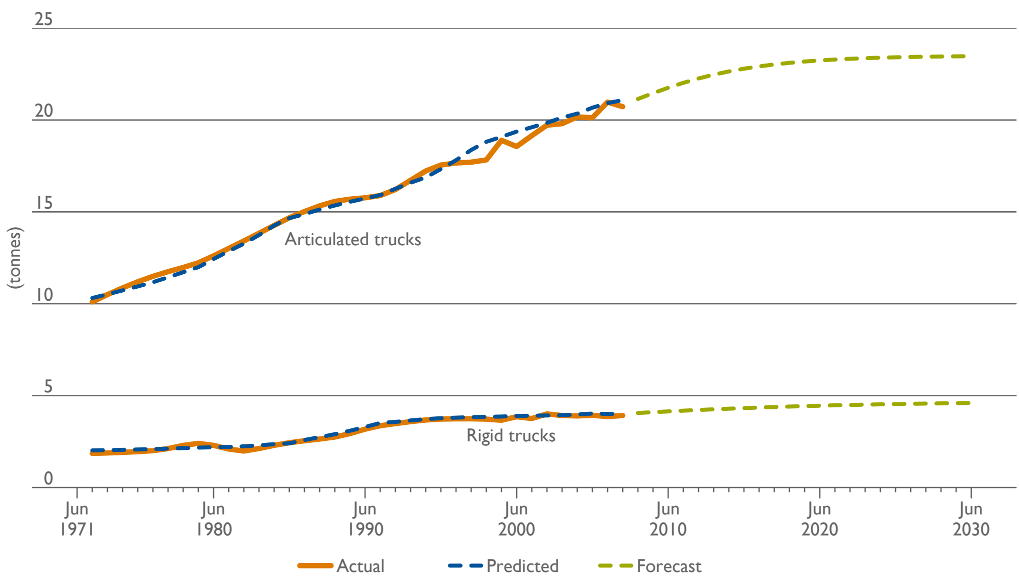
Under this scenario, articulated truck average loads are projected to increase to around 21.9 tonnes per vehicle kilometre by 2030, growing by approximately 0.14 per cent per annum between 2010 and 2030. The projections imply that while average loads will continue to increase over the next decade, as the share of freight carried by B-doubles increases, the growth in fleet-wide articulated truck average loads will be much slower than previously due to saturation of

B-double's freight share. Rigid truck average loads are projected to increase only slightly to 4.6 tonnes per vehicle kilometre by 2030. Figure 4.3 shows the projected growth in rigid and articulated trucks average loads.

## No further regulatory change – higher B-double share

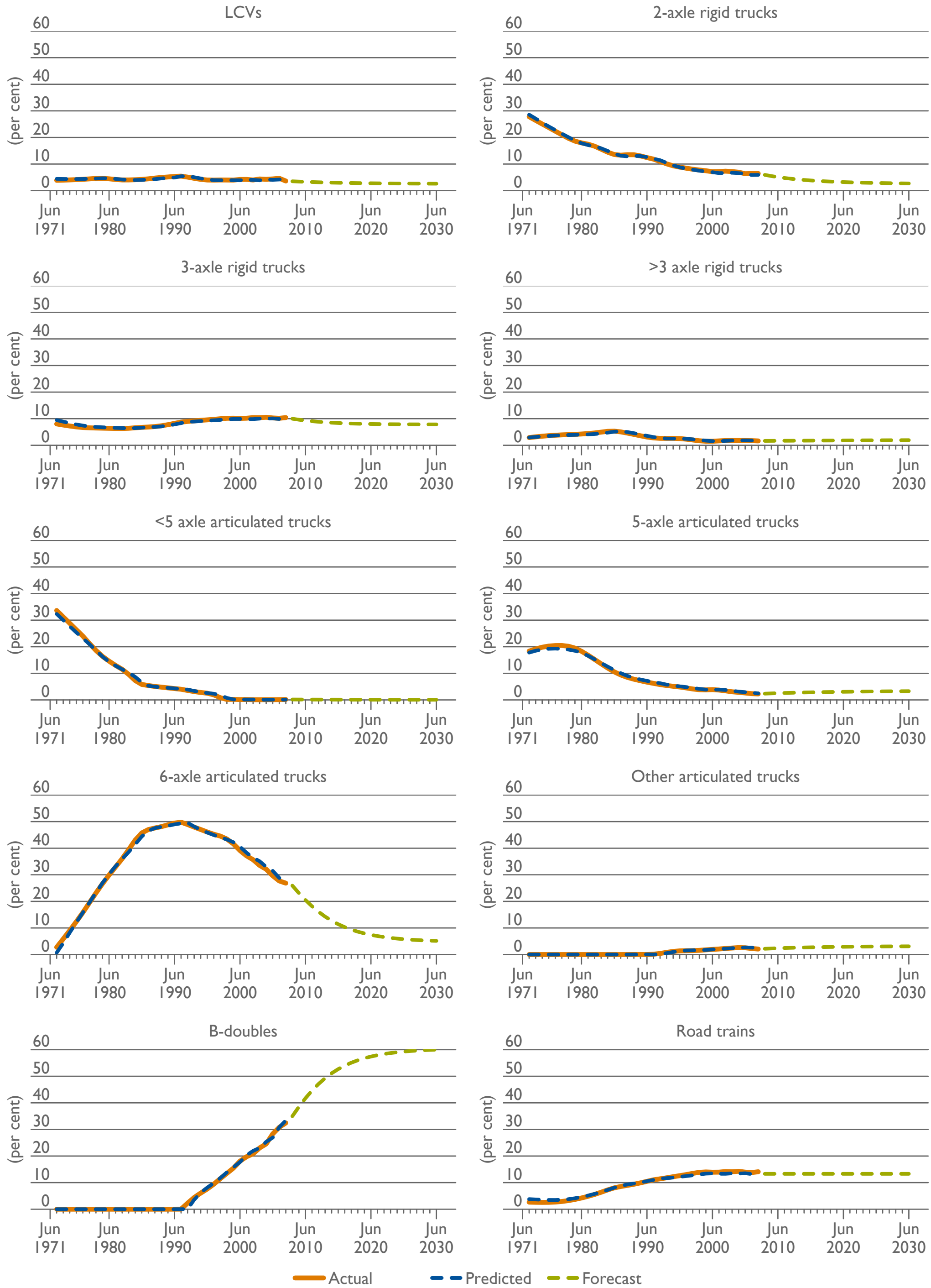
The freight share model projects that the share of freight carried by road trains will decline slightly into the future, from around 16 per cent currently to around 10 per cent by 2030, and the share of freight carried by six-axle articulated trucks declines to around 17 per cent by 2030. A decline in the share of freight carried by road trains implies that growth in road train freight is below the average rate of growth in total road freight. An alternative, and arguably equally plausible, scenario is that B-double's attract more freight from six-axle articulated trucks, accounting for around 60 per cent of total road freight by 2030, and the share of freight carried by road trains does not decline between 2010 and 2030, such that the total share of freight carried by articulated trucks between 2010 and 2030 is the same as under the default scenario (Figure 4.2). The assumed commercial vehicle road freight shares are shown in Figure 4.5. Under these assumptions projected future rigid truck average loads are unchanged (see Figure 4.4), but articulated truck average loads are projected to increase to around 23.5 tonnes per vehicle kilometre by 2030, an implied average rate of growth of 0.5 per cent per annum. This is, however, still well below the rate of growth in articulated truck average loads observed over the past 15 years.

F4.4 Actual and projected average loads, 1971–2030, no further reform and assumed higher B-double share




Source: BITRE estimates.

**F4.5** Actual and assumed future heavy vehicle freight shares, 1971–2030, no further reform and assumed higher B-double share, by detailed commercial vehicle class




Source: BITRE estimates.

## *Minimal PBS/IAP network access scenario*

This scenario models the impact of B-triple and AB-triple access to road train routes on future truck-specific freight shares and fleet average loads. For simplicity, the modelled scenario assumes that AB-triples would be used in preference to B-triples on road train routes and consequently B-triples were not included among the modelled vehicle types under the this scenario. AB-triple mass limits are assumed to be 102.5 tonnes under GML, 104.5 tonnes under CML and 113.0 tonnes under HML, which is consistent with current regulated axle group mass limits. The maximum allowable length of AB-triple vehicles is assumed to be 36.5 metres. AB-triple annual vehicle registration charges are $17 542 in 2010–11, and are assumed to remain constant relative to registration charges of other freight vehicle types over the forecast horizon.[17] The average fuel consumption rate of AB-triples is assumed to be around 68 litres per 100 kilometres, less than the average rate of fuel consumption of triple trains.

AB-triples have higher payload carrying capacity than double road trains, but less than that of triple road trains, and are more likely to be preferred on road train routes restricted to double road trains. Presently, triple road trains are only allowed on very remote parts of the network in Queensland, Western Australia, South Australia and the Northern Territory. Double road trains are allowed to operate on a wider network of roads, and it is on these roads where AB-triples might provide productivity benefits. Figure 4.6 illustrates PBS vehicle road network access across the non-urban road network and Table 4.1 lists vehicle access levels. Double road trains are permitted to operate on PBS Level 3 and Level 4 network roads and triple road trains are restricted to PBS Level 4 network roads. Assignment of the BITRE (2009a) estimated 2005 interregional long-distance road freight task, shown in Figure 4.7, implies that approximately 14 per cent of all road freight used PBS Level 3 roads and 5 per cent of all road freight used PBS Level 4 roads in 2005.[18]

**T4.1** Road classes and heavy vehicle access levels

| Road class | Smart heavy vehicle type | Vehicle description | Vehicle length (*m*) | |
|---|---|---|---|---|
| | | | Access Class 'A' | Access class 'B' |
| Level 1 | 1 | Single articulated trucks | $L \leqslant 20$ | |
| Level 2 | 2 | B-doubles | $L \leqslant 26$ | $26 < L \leqslant 30$ |
| Level 3 | 3 | Double road train (Type I) | $L \leqslant 36.5$ | $36.5 < L \leqslant 42$ |
| Level 4 | 4 | Triple road train (Type II) | $L \leqslant 53.5$ | $53.5 < L \leqslant 60$ |

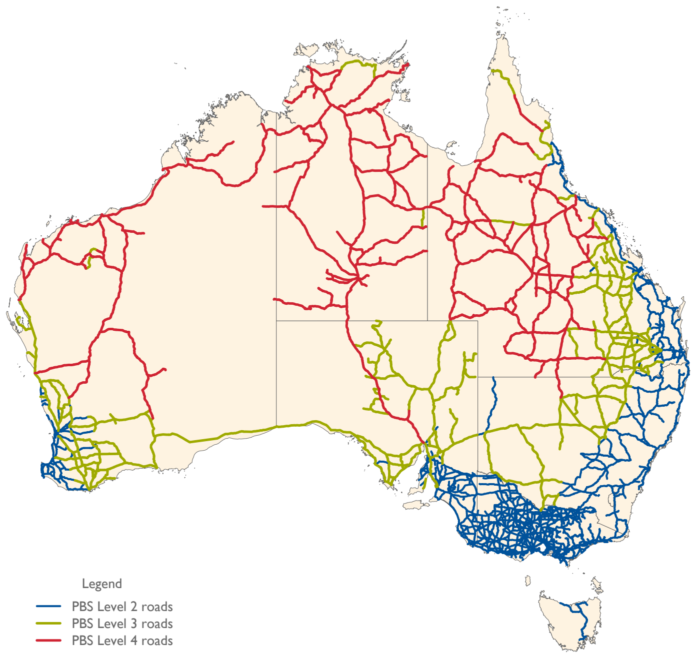
Source: NTC (2009c)

Under these assumptions, the share of freight carried by AB-triples is projected to increase from currently negligible levels to approximately 3 per cent of total road freight by 2030, potentially attracting a considerable proportion of freight currently carried by double road trains. Total road freight carried by road trains, including AB-triples, is projected be around 16 per cent by 2030, above the 'no further regulatory change' scenario. Figure 4.8 shows the detailed vehicle type freight task projections.

As the projected increase in the share of freight carried on road train routes by AB-triples comes at the end of the projection horizon, it has only a minimal impact on fleet-wide average vehicle loads—increasing articulated truck average loads by approximately 0.15 tonnes over the 'no further reform' scenario, to be approximately 22.0 tonnes per vehicle kilometre in 2030. Rigid

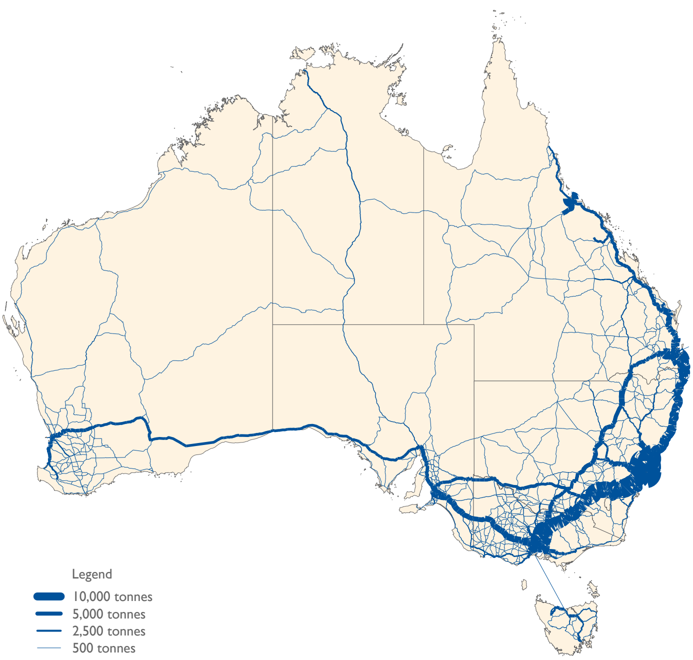
17 In the GEV heavy vehicle freight share model, it is changes in relative costs that influence freight shares.
18 The sum of assigned freight volumes across PBS Level 3 and Level 4 network roads—19 per cent—is reasonably similar to the SMVU estimate of road train's freight share in 2005—approximately 16 per cent.

## F4.6 PBS road network access



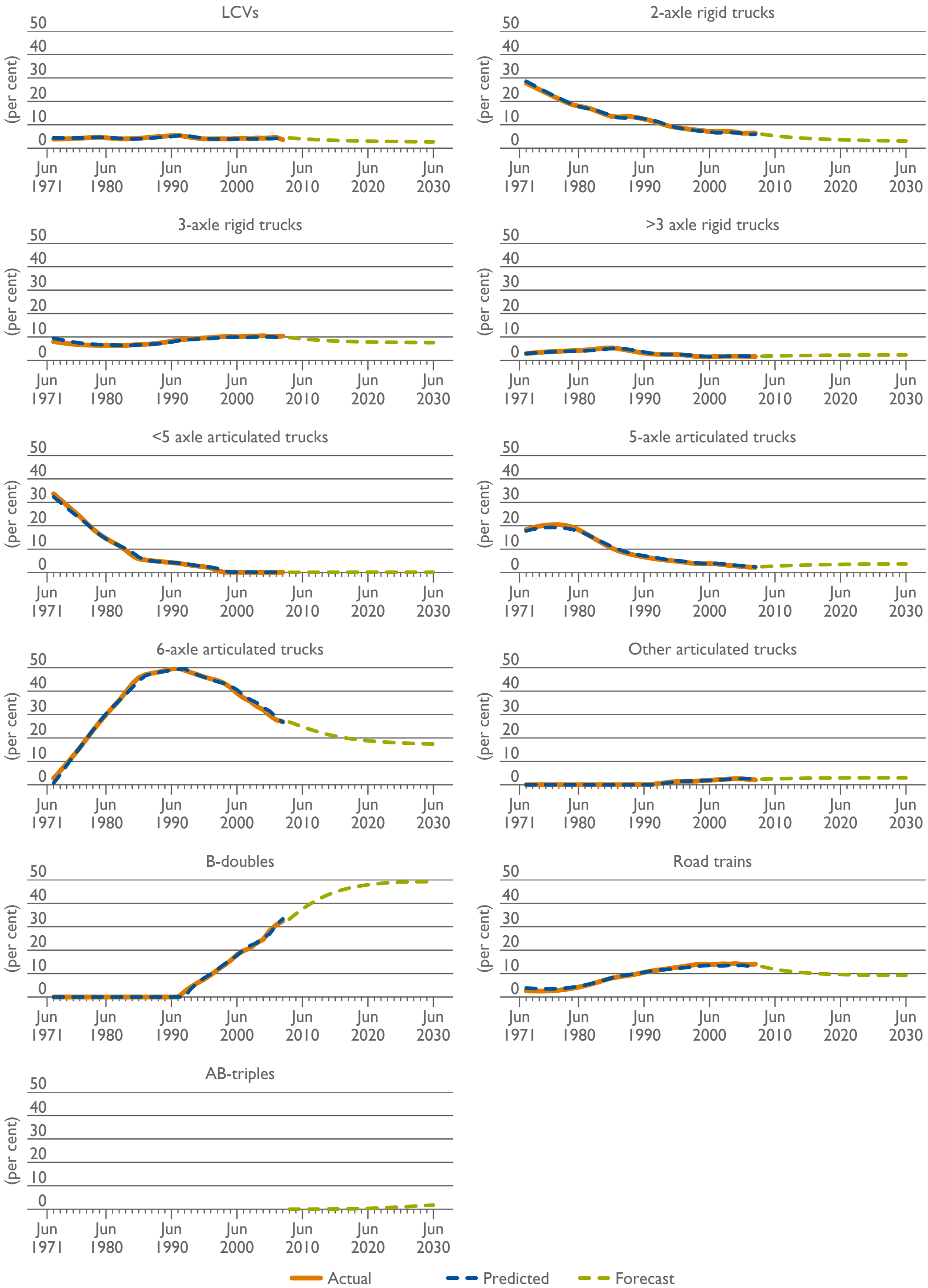

Source: Based on NTC Performance Based Standards Network Map (www.ntc.gov.au).

## F4.7 Assigned interregional road freight, 2005



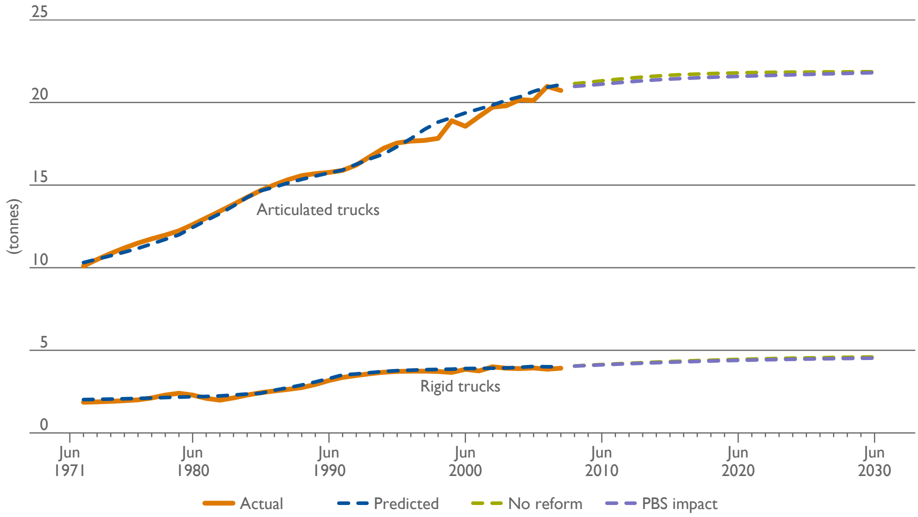

Source: BITRE (2009a).

**F4.8** Actual and projected heavy vehicle freight shares, 1971–2030, PBS minimal impact scenario, by detailed commercial vehicle class




Source: BITRE estimates.

F4.9 Actual and projected average loads, 1971–2030, PBS minimal impact scenario




Source: BITRE estimates.

truck average loads are projected to be similar to the 'no further reform' scenario—around 4.6 tonnes per vehicle kilometre in 2030. Figure 4.9 shows the projected growth in rigid and articulated trucks average loads.

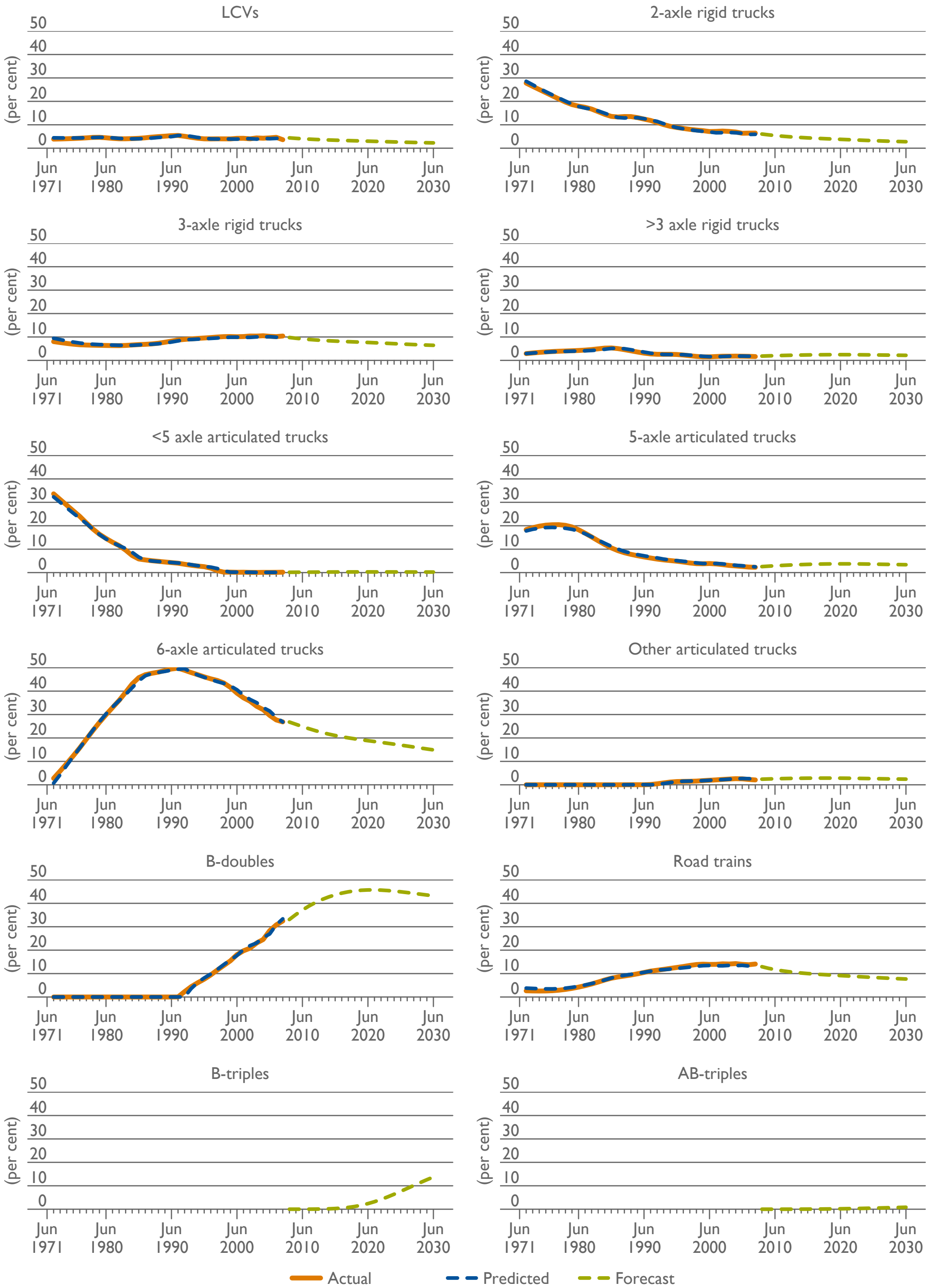
## *Extended PBS/IAP network access scenario*

The extended PBS/IAP network access scenario models the impact of extending access to the existing B-double network to B-triples, outside urban areas, and AB-triple access to road train routes on future truck-specific freight shares and fleet average loads. The modelled scenario assumes B-triple mass limits are 82.5 tonnes under GML, 84.5 tonnes under CML and 90.5 tonnes under HML, and a maximum allowable vehicle length of 36.5 metres. B-triple annual vehicle registration charges were approximately $21 712 in 2010–11, and are assumed to remain constant relative to registration charges of other freight vehicle types over the forecast horizon. The average fuel consumption rate of B-triples is assumed to be around 62 litres per 100 kilometres, above the average rate of fuel consumption of B-doubles but below the average rate of fuel consumption of double road trains and AB-triples. AB-triple mass limits, length limits and annual vehicle registration charges are as per the minimal IAP/PBS network access scenario.

B-triples offer a 30 per cent increase in gross mass and a similar proportionate increase in payload over existing B-doubles. B-doubles already carry a significant proportion of total road freight, and opportunities to use B-triples in place of B-doubles for non-urban freight would significantly lift the productivity of road freight vehicles. However, the productivity impact of B-triple availability is likely to be proportionately less than that produced by the introduction of B-doubles in the late 1980s, for two reasons: (i) the proportionately smaller network over which B-triples would be allowed to operate; and (ii) the smaller proportionate increase in average gross mass between B-triples and B-doubles than that obtained from substitution of B-doubles for six-axle articulated trucks.[19]

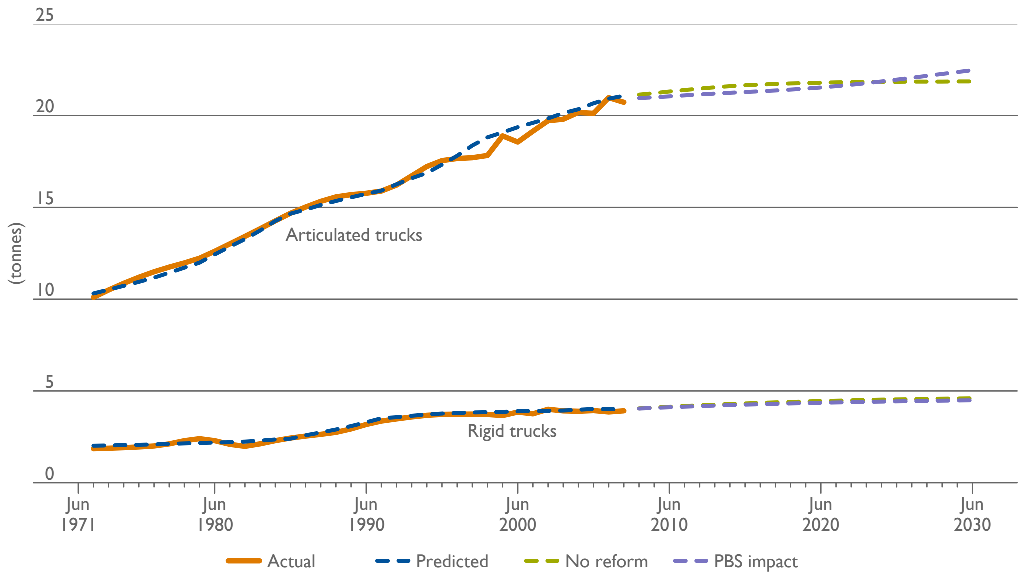
19 B-double GVM and payload carrying capacity is nearly 50 per cent above that of six-axle articulated trucks.

F4.10 Actual and projected heavy vehicle freight shares, 1971–2030, PBS extended impact scenario, by detailed commercial vehicle class




Source: BITRE estimates.

F4.11 Actual and projected average loads, 1971–2030, PBS extended impact scenario




Source: BITRE estimates.

Under this scenario, the share of freight carried by B-triples is projected grow from currently negligible levels to approximately 17 per cent of total road freight by 2030, attracting a considerable proportion of freight that would otherwise have been carried by B-doubles. B-double's freight share is projected to continue to increase between 2010 and 2020, from around 40 per cent in 2010 to 45 per cent in 2020, but declines thereafter as more freight is carried by B-triples. The share of freight carried by six-axle articulated trucks continues to shrink, as the proportion of freight carried by larger heavy vehicle classes increases. The share of road freight carried by road trains and AB-triples, is also projected to shrink to around 10 per cent by 2030, which is less than the road train share under the 'no further regulatory change' scenario. Interestingly, the share of freight carried by AB-triples is projected to increase by only a very small amount under this scenario, with B-triples taking most of the freight that would have been carried by AB-triples. Figure 4.10 shows the detailed vehicle type freight task projections.

Figure 4.11 shows the projected growth in fleet-wide rigid and articulated truck average loads. The projected increase in the share of freight carried by B-triples has a more significant impact on fleet-wide average vehicle loads—increasing articulated truck average loads by approximately 0.5 tonnes per vehicle kilometre by 2030 relative to the 'no further reform' scenario, to 22.5 tonnes per vehicle kilometre. There is a significant up-tick in articulated truck average loads from 2020 onwards, which is likely to continue beyond 2030 were the forecasting horizon extended. This result implies that the more widespread the uptake of higher productivity vehicles, the larger the impact on fleet-wide average vehicle productivity. Rigid truck average loads are projected to be slightly less than under the 'no further reform' scenario, around 4.5 tonnes per vehicle kilometre.

# 4.3 Alternative scenarios and heavy vehicle productivity

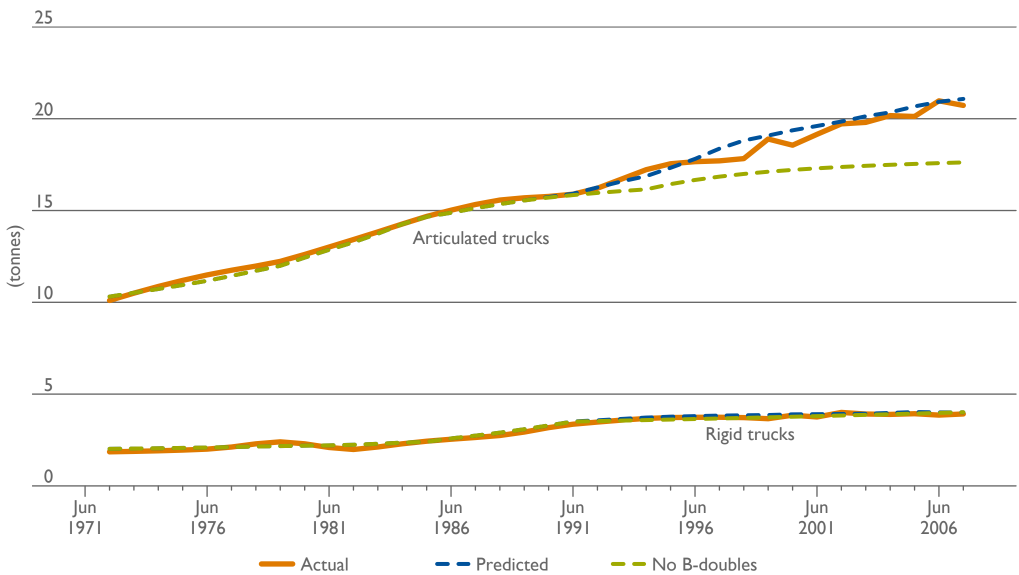
## *No B-doubles counterfactual*

The 'no B-doubles' counterfactual scenario models the impact on current heavy vehicle freight shares and fleet-wide average loads assuming that B-doubles had not been introduced in the late 1980s. The heavy vehicle freight share model includes a B-double availability dummy variable, that covers the period prior to the introduction of B-doubles. The counterfactual scenario is modelled by assuming the availability dummy variable applies to the entire historical sample period, 1971 to 2007.

Under this scenario, the model predicts the share of freight carried by six-axle articulated trucks would have stabilised at around 50 per cent beyond 1990, and the share of freight carried by smaller articulated trucks and rigid trucks would not have declined as quickly as actually occurred following the introduction of B-doubles. The share of freight carried by road trains would have been approximately 14 per cent of total freight, similar to the current situation. Total articulated truck freight would have accounted for less than 80 per cent of total road freight, slightly below the current share, and rigid trucks' freight share would have been slightly higher than currently. Figure 4.13 shows the predicted freight shares under this counterfactual relative to the actual shares between 1990 and 2007 for the detailed vehicle types. The broad commercial vehicle class (i.e. LCVs, rigid trucks and articulated trucks) freight shares for this counterfactual are very similar to the actual values.

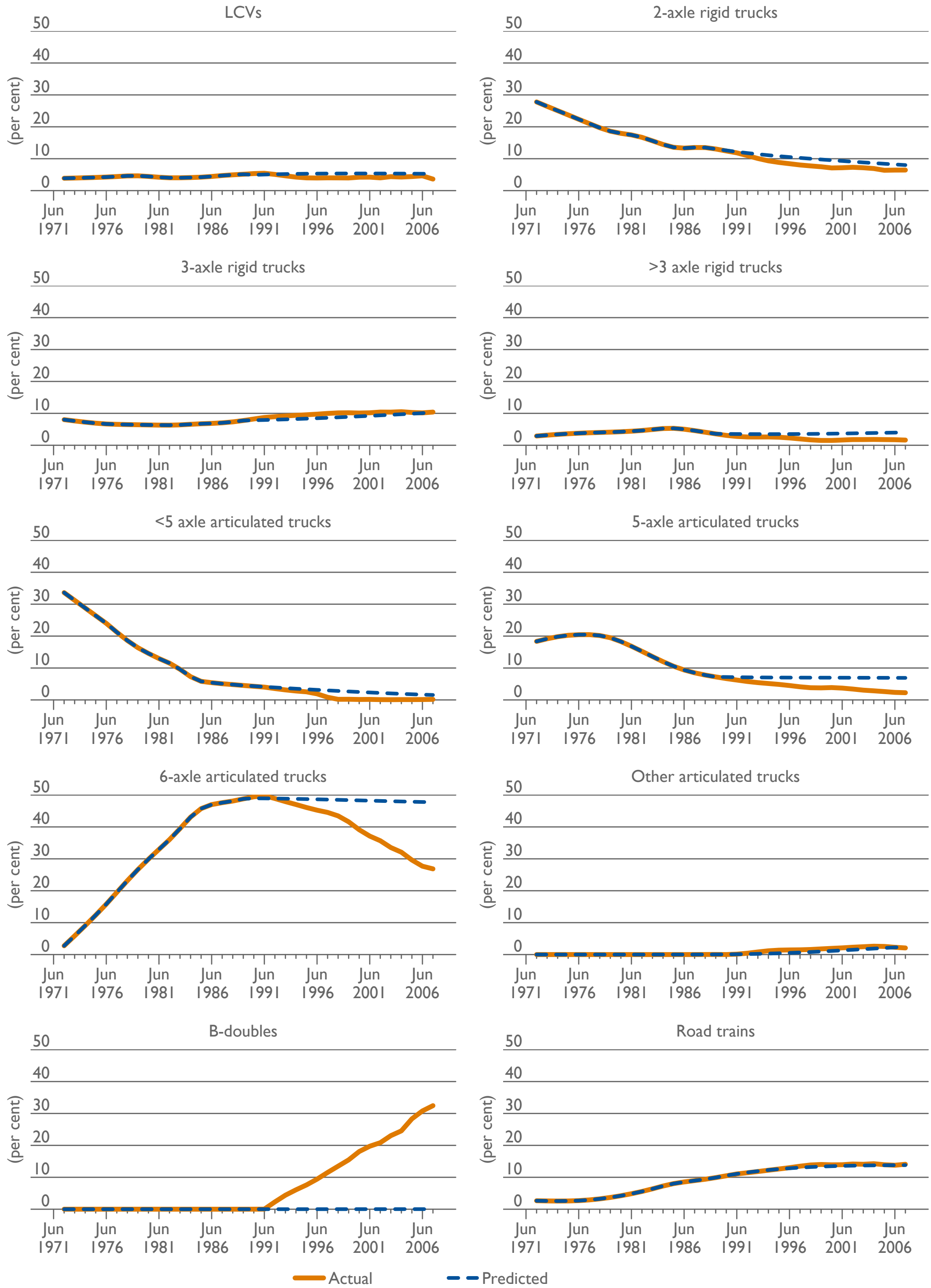
The counterfactual predicted freight shares imply that fleet-wide articulated truck average loads

**F4.12** Actual and predicted average loads, 1971–2007, no B-doubles counterfactual scenario




Source: BITRE estimates.

F4.13 Actual and projected heavy vehicle freight shares, 1971–2030, no B-doubles counterfactual scenario, by detailed commercial vehicle class




Source: BITRE estimates.

would have been 17.5 tonnes per vehicle kilometre in 2007, approximately 16 per cent, or 3 tonnes, lower than actual articulated truck average load in 2007. Figure 4.12 shows the actual average loads for rigid and articulated trucks and the predicted articulated truck average load for the no B-doubles counterfactual. Assuming that average utilisation of six-axle articulated trucks would have been identical to that of the B-doubles that have replaced them, without B-doubles the 2007 road freight task would have required an additional 5 600 vehicles—or 13 per cent more articulated trucks—and involved an additional 1.1 million truck kilometres—or 16 per cent more articulated truck travel—in comparison with actual articulated truck freight in 2007.

## *Ten per cent increase in GML*

An increase in vehicle mass limits adds directly to heavy vehicle productivity by allowing more mass carrying capacity for each affected vehicle. Two GML increase scenarios were modelled. The first scenario modelled the impact of a uniform ten per cent increase in the maximum allowable gross mass across all rigid and articulated trucks from 2010 onwards. All other factors were assumed to remain as per the no further regulatory reform scenario. Relative to the no further reform scenario, this scenario has only a negligible impact on future heavy vehicle freight shares. However, the increase in GML results in increased average vehicle payloads—the analysis suggests that for every one tonne increment in allowable gross vehicle mass, average loads increase by approximately 0.5 tonnes—and an increase in fleet-wide average loads. Allowing for the gradual uptake of increased mass by industry, the impact of a uniform increase in mass limits would see fleet-wide articulated truck average loads increase to around 23.5 tonnes per vehicle kilometre and rigid truck average loads to 5.0 tonnes per vehicle kilometre by 2030. This is almost 3 tonnes per vehicle kilometre above current articulated truck average loads and 1.5 tonnes above projected articulated truck average loads in 2030 in the absence of any further reform. Figure 4.14 shows the projected growth in rigid and articulated trucks average loads under the no further reform scenario and the uniform ten per cent GML increase scenario.

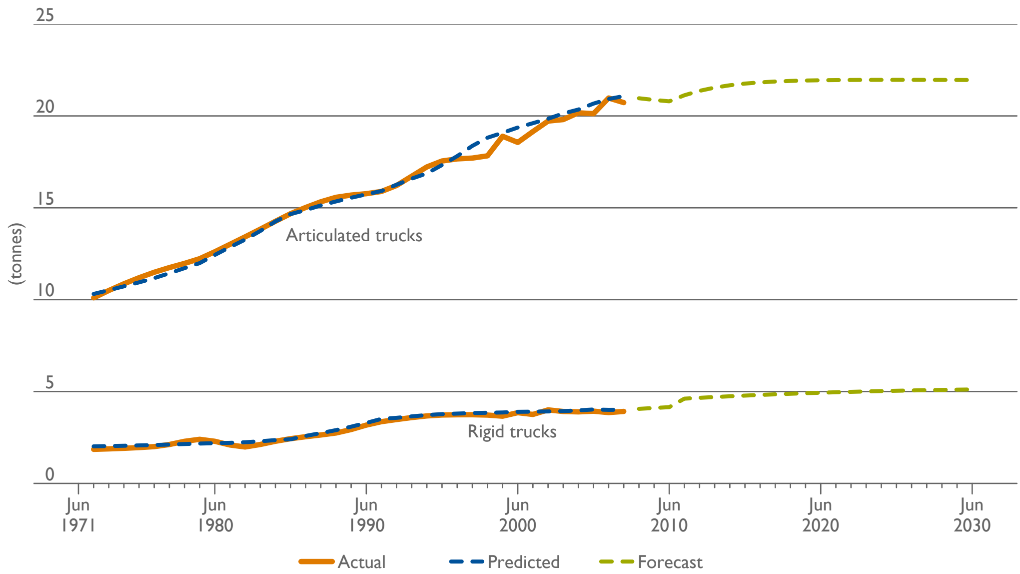
Of all the alternative scenarios presented here, this scenario produces the largest potential future increase in fleet-wide average loads. This contrasts with historical experience where changes in heavy vehicle freight shares contributed most of the the growth in heavy vehicle productivity. However, with B-double freight shares approaching saturation and the share of road train freight unlikely to expand greatly, changes in freight shares are likely to provide much less scope for future heavy vehicle productivity growth.

The second scenario modelled the impact of a ten per cent increase in GML for six-axle articulated trucks only from 2010 onwards. GML applying to other heavy vehicle classes were assumed to remain constant. Under these assumptions, the share of freight carried by six-axle articulated trucks is still projected to decline to around 17 per cent by 2030, albeit the share would be slightly higher than under the no further reform scenario. This result is not surprising as the elasticity of vehicle type freight share with respect to GML is very low. The impact on fleet-wide articulated truck average loads is more muted, raising average loads by approximately 0.15 tonnes per vehicle kilometre. Rigid truck average loads would be similar to the 'no further reform' scenario.

## *Estimated impact of recent increases in B-double and road train registration charges*

Figure 3.13 showed that, since the introduction of uniform national heavy vehicle charges in 1995, real heavy vehicle registration charges have generally declined across most heavy vehicle

F4.14 Actual and projected average loads, 1971–2030, ten per cent GML scenario




Source: BITRE estimates.

categories. Figure 3.13 also showed the impact of the phased implementation of the 2007 revisions to B-doubles and road train registration charges—removing the implicit subsidy to these vehicle types—applied over the three years to 2010. The effect of these recent revisions has been to increase (nine-axle) B-double registration charges by 90 per cent in the three years since 2007 and by over 70 per cent relative to that of most other heavy vehicle types. Road train registration charges have increased 27 per cent over the same period, and by over 15 per cent relative to registration charges for most other heavy vehicle types.

The freight share model elasticity results, presented in Table 3.3, can be used to estimate the impact of changes in B-double and road train vehicle registration charges on long-run freight shares. Recognising that vehicle registration charges for high utilisation B-doubles typically represent less than 5 per cent of total vehicle operating costs, and noting that aggregate vehicle type freight share is relatively unresponsive (inelastic) with respect to total vehicle operating costs, the model implies that the increase in B-double registration charges between 2007 and 2010 would have reduced B-double's aggregate road freight share by 0.19 per cent in the long run, equivalent to a reduction in B-double road freight, as a proportion of total road freight, of approximately 0.05 per cent. (It is important to note, however, that the increase in B-double registration charges between 2007 and 2010 is well beyond the range of previous modelled cost increases and that market responsiveness may vary with the magnitude of the increase in overall cost. Therefore, the model may underestimate the impact of changes in registration charges. Nonetheless, the impact on B-double's freight share is likely to be relatively small.) The impact of the increase in road train registration charges between 2007 and 2010 on total freight carried by road trains is likely even smaller than that for B-doubles, as both the proportionate increase in registration charges is far less than that for B-doubles and the freight share cost elasticity for road trains is smaller than that of B-doubles.

## 4.4 Implications and model limitations

This chapter has presented estimates of likely future trends in heavy vehicle average loads, using the model described in Chapter 3. The results imply that, in the absence of further reform, there will be some continued growth in fleet-wide average vehicle loads into the future, as the share of freight carried by B-doubles increases, but future productivity growth will be slower than over the previous decade. The increased uptake of higher productivity heavy vehicles available under PBS will provide some additional productivity growth, but because many of these vehicles are limited to remote and rural routes, which account for a fraction of total road freight, the impact on fleet-wide average road freight vehicle productivity will be relatively small. If, however, B-triples were used on B-double approved non-urban highways future freight vehicle productivity growth would be potentially greater. Even under this scenario, projected future heavy vehicle productivity growth will not match growth experienced over the last 15 years. Of all the scenarios presented here, a uniform increase in mass limits would have the most significant impact on heavy vehicle productivity.

The PBS scenarios are intended to be illustrative of the potential impact of increased uptake of PBS vehicle on aggregate heavy vehicle productivity. The range of freight vehicle configurations potentially available under PBS is quite large and it is beyond the scope of the 'top-down' road freight share model presented here to accurately model the likely take-up of all possible PBS vehicle combinations. A 'bottom-up' model, which modelled heavy vehicle freight shares using origin–destination (OD) freight movements assigned to the road network, could complement the top-down model presented here and potentially better model the range and take-up of the wide variety of alternative PBS vehicle options. Development of such a model would require collection of more current OD-level freight movements data, data which is presently not available.

Nonetheless, the implication of these scenarios is that we are nearing the limits of productivity growth achievable from previous regulatory reforms, and that road freight vehicle productivity will continue to increase but at a declining rate. Even with relatively strong uptake of larger heavy vehicles available under PBS, the improvement in road freight productivity growth is unlikely to match growth experienced over the last three decades.

# CHAPTER 5
# Concluding remarks

This report has provided an overview of historical trends in road freight activity and road freight vehicle productivity, outlined the influence of different factors on productivity growth and presented some scenarios of potential future growth in road freight productivity.

## 5.1 How significant has road freight vehicle productivity growth been?

The physical productivity of the Australian road freight vehicle fleet—measured as the annual volume of freight divided by the number of registered freight vehicles—more than doubled between 1971 and 2007. As a consequence, transport of total road freight in 2007 required less than half as many freight vehicles than the equivalent task would have required in 1971.

The growth in road freight vehicle productivity has been even more pronounced among heavy freight vehicles—rigid and articulated trucks. The average physical productivity of heavy vehicles grew almost six-fold between 1971 and 2007. Approximately two thirds of the increase in heavy vehicle productivity, between 1971 and 2007, was attributable to increases in average load per vehicle kilometre and one-third to increased vehicle utilisation.

Articulated trucks account for approximately 93 per cent of the improvement in total freight productivity, and almost 99 per cent of total heavy vehicle productivity growth over this period.

Other partial road freight productivity indicators, such as freight per unit of fuel and freight per unit of labour, also exhibited strong growth between 1971 and 2007. For example, fuel consumed per freight tonne kilometre carried by heavy vehicles more than halved between 1971 and 2007, from around 8.1 litres per 100 tonne kilometres to 3.5 litres per 100 tonne kilometres.

Significantly, the rate of growth in fleet-wide average freight vehicle productivity has been declining over time. Heavy freight vehicle productivity grew twice as fast between 1971 and 1991 than between 1991 and 2007. This is reflected across both rigid and articulated trucks and includes the impact of B-double uptake, which has essentially all occurred since 1991.

## 5.2 What have been the major factors influencing vehicle productivity growth?

Since 1971 there have been significant technological and regulatory-led changes that have influenced freight vehicle productivity growth.

Growth in the share of freight carried by larger freight vehicle combinations has been by far the most significant contributor to growth in road freight vehicle productivity over the last four decades, accounting for approximately 80 per cent of the cumulative increase in rigid and articulated truck average vehicle loads. Provision of network access for new heavy vehicle combinations and expansion of network access for existing heavy vehicle combinations appear to have been the most influential factors in increased vehicle productivity. The growth in the share of freight carried by larger heavy vehicle combinations increases both the average freight carried per vehicle and the average load per vehicle kilometre. The growth in the share of long-distance road freight, for which larger freight vehicle combinations are more efficient and cost effective, has also contributed to the growth in the share of freight carried by larger freight vehicles.

Cumulative investment in upgrading and duplicating parts of the national highway system and harmonisation of light and heavy vehicle speed limits have also contributed to the growth in long-distance road freight.

Progressive relaxation of regulated mass and vehicle dimension limits, permitting higher mass and larger volume cargoes to be carried by existing heavy vehicle combinations is estimated to have contributed approximately 20 per cent of the overall growth in heavy vehicle productivity since 1971.

## 5.3 What does the future hold?

The report also presents a model relating trends in vehicle type freight shares to historical changes in vehicle costs and freight vehicle regulations. The model provides a tool for projecting future trends in heavy vehicle productivity.

The model results imply that, with no further significant reform, and assuming that average loads within each modelled heavy vehicle class remain unchanged, fleet-wide average loads are likely to grow by less than 10 per cent between 2010 and 2030—an average annual rate of growth of 0.3 per cent per annum. This is well below growth in average vehicle loads experienced since 1991—approximately 2.0 per cent per annum. In effect, this scenario implies that past heavy vehicle reforms continue to exert an influence on heavy vehicle freight shares, contributing to increasing heavy vehicle productivity (average loads), but that the potential future impact of past reforms is rapidly diminishing.

The model also implies that had B-doubles not been introduced in the late-1980s, the fleet-wide average load would be around 16 per cent lower than it actually was in 2007 and carriage of the 2007 freight task would have required an additional 5000 to 6000 thousand heavy vehicles and involved an additional 1.1 million kilometres heavy vehicle travel.

The report also estimates the impact on fleet average loads of increased uptake of larger heavy vehicle combinations allowed under PBS—such as B-triples and AB-triples. Under current arrangements, AB-triples and B-triples are allowed to operate on PBS accessible network roads, which are primarily in rural and remote areas. The modelling presented here implies that increased use of these vehicles could potentially account for around 3 per cent of all road freight by 2030. Because these vehicles are only able to operate across a fraction of the total road network, their impact on fleet-wide average loads would be relatively minor.

If, however, network access for PBS vehicles were extended, permitting B-triples to operate on most intercapital highways outside urban areas, the share of freight carried by these vehicle types could be as much as 17 per cent of freight by 2030. Under these assumptions, fleet-wide articulated truck average loads could increase to around 22.5 tonnes by 2030, equivalent to annual average growth in articulated truck average loads of 0.3 per cent per annum, still less than trend growth in average loads between 1991 and 2007 (approximately 1.64 per cent per annum).

By contrast, the model implies a 5 or 10 per cent increase in GML could result in a 4 and 8 per cent cumulative increase in fleet-wide average loads. This is larger than the projected potential increase in fleet average load likely to result from increased use of PBS vehicles, as the increase in GML would apply to a much larger share of the total freight task. The result contrasts with historical experience, where changes in freight share accounted for the majority of freight productivity growth, because the freight shares of larger combination freight vehicles are nearing saturation.

## 5.4 Final remarks

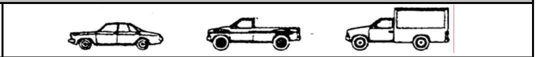
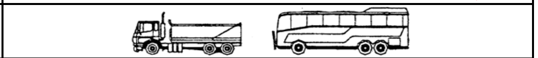
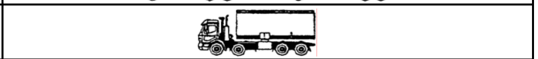
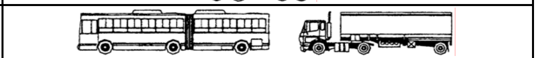
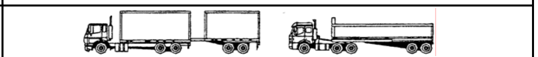
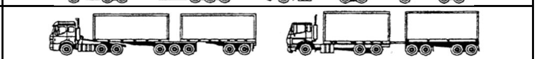
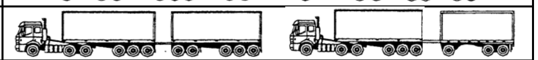
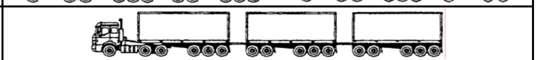
The introduction and take-up of six-axle articulated trucks and B-doubles yielded very large increases in heavy vehicle payloads and heavy vehicle productivity—six-axle articulated truck average loads were typically 30 per cent higher than that of five-axle articulated trucks they generally replace, and B-double average loads were typically 50 per cent higher than those of the six-axle articulated trucks they replaced. These two vehicles, together with the increasing share of longer-distance freight carried by larger heavy vehicles, contributed greatly to the growth in heavy vehicle productivity over the past three decades.

While the uptake and increased utilisation of higher productivity vehicles available under PBS, and the IAP program, will deliver productivity increases in particular markets, it is unlikely that the productivity gains delivered by these changes can match previous productivity growth. Nonetheless, any marginal improvements in heavy vehicle productivity will provide important efficiency gains across different parts of the freight supply chain.

As a consequence, future road freight productivity growth is likely to be more modest than previously and accommodating the projected future growth in road freight will require more vehicles and more drivers. It may also present greater opportunities for rail to carry a larger share of the domestic freight task.

# APPENDIX A
# Austroads vehicle classification

## FA.1 Austroads vehicle classification system

| Level 1 Length (indicative) | Level 2 Axles and Axle Groups | | Level 3 Vehicle Type | AUSTROADS Classification | | |
|---|---|---|---|---|---|---|
| **Type** | **Axles** | **Groups** | **Typical Description** | **Class** | **Parameters** | **Typical Configuration** |
| | **LIGHT VEHICLES** | | | | | |
| **Short** up to 5.5m | | 1 or 2 | **Short** Sedan, Wagon, 4WD, Utility, Light Van, Bicycle, Motorcycle, etc | **1** | d(1) ≤ 3.2m and axles = 2 |  |
| | 3, 4 or 5 | 3 | **Short - Towing** Trailer, Caravan, Boat, etc | **2** | groups = 3 d(1) ≥ 2.1m, d(1) ≤ 3.2m, d(2) ≥ 2.1m and axles = 3, 4 or 5 |  |
| | **HEAVY VEHICLES** | | | | | |
| **Medium** 5.5m to 14.5m | 2 | 2 | **Two Axle Truck or Bus** | **3** | d(1) > 3.2m and axles = 2 |  |
| | 3 | 2 | **Three Axle Truck or Bus** | **4** | axles = 3 and groups = 2 |  |
| | > 3 | 2 | **Four Axle Truck** | **5** | axles > 3 and groups = 2 |  |
| **Long** 11.5m to 19.0m | 3 | 3 | **Three Axle Articulated** Three axle articulated vehicle, or Rigid vehicle and trailer | **6** | d(1) > 3.2m, axles = 3 and groups = 3 |  |
| | 4 | > 2 | **Four Axle Articulated** Four axle articulated vehicle, or Rigid vehicle and trailer | **7** | d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 4 and groups > 2 |  |
| | 5 | > 2 | **Five Axle Articulated** Five axle articulated vehicle, or Rigid vehicle and trailer | **8** | d(2) < 2.1m or d(1) < 2.1m or d(1) > 3.2m axles = 5 and groups > 2 |  |
| | ≥ 6 | > 2 | **Six Axle Articulated** Six axle articulated vehicle, or Rigid vehicle and trailer | **9** | axles = 6 and groups > 2 or axles > 6 and groups = 3 |  |
| **Medium Combination** 17.5m to 36.5m | > 6 | 4 | **B Double** B Double, or Heavy truck and trailer | **10** | groups = 4 and axles > 6 |  |
| | > 6 | 5 or 6 | **Double Road Train** Double road train, or Medium articulated vehicle and one dog trailer (M.A.D.) | **11** | groups = 5 or 6 and axles > 6 |  |
| **Large Combination** Over 33.0m | > 6 | > 6 | **Triple Road Train** Triple road train, or Heavy truck and three trailers | **12** | groups > 6 and axles > 6 |  |

**Definitions:**
Group: Axle group, where adjacent axles are less than 2.1m apart
Groups: Number of axle groups
Axles: Number of axles (maximum axle spacing of 10.0m)

d(1): Distance between first and second axle
d(2): Distance between second and third axle

Source: Reproduced from Transport SA (2006).

# APPENDIX B
# Vehicle productivity growth decomposition

Chapter 2 decomposed physical heavy vehicle productivity growth into three components:

- vehicle share contribution
- average load contribution and
- average VKT contribution

by broad commercial vehicle type—LCVs, rigid trucks and articulated trucks. This appendix briefly outlines the vehicle productivity growth decomposition.

Let $f_{it}$ denote total freight (tonne kilometres) moved by vehicle type $i$ in period $t$, and $x_{it}$ be the number of vehicles of type $i$ in period $t$.

Average productivity of vehicle type $i$ is defined as total freight divided by the number of vehicles (and denoted by $y_{it}$):

$$y_{it} = \frac{f_{it}}{x_{it}}$$

Total freight moved by vehicle type $i$ is the product of average load of vehicle type $i$ ($l_{it}$), average VKT ($v_{it}$) and the number of vehicles ($x_{it}$).

Fleet average productivity in period $t$ ($y_t$) is:

$$y_t = \frac{\sum_{i=1}^{N} f_{it}}{\sum_{i=1}^{N} x_{it}}$$

Substituting for $f_{it}$ gives:

$$y_t = \frac{\sum_{i=1}^{N} l_{it} v_{it} x_{it}}{\sum_{i=1}^{N} x_{it}} = \sum_{i=1}^{N} S_{it}\, l_{it}\, v_{it}$$

where $S_{it} = x_{it} / \left(\sum_{i=1}^{N} x_{it}\right)$ denotes the share of commercial vehicles comprised by vehicle type $i$ at time $t$.

The change in fleet average productivity between period $t$ and period $t+k$ is given by $\Delta_k y_t = y_{t+k} - y_t$:

$$\Delta_k y_t = \sum_{i=1}^{N} \left[ S_{i,t+k} \left( l_{i,t+k} v_{i,t+k} \right) - S_{it} \left( l_{it} v_{it} \right) \right]$$

This may be decomposed into weighted average productivity and vehicle share effects:

$$\Delta_k y_t = \sum_{i=1}^{N} \left[ \frac{(S_{i,t+k} + S_{it})}{2} \left( l_{i,t+k}\, v_{i,t+k} - l_{it}\, v_{it} \right) \right. \\ \left. + \frac{(l_{i,t+k}\, v_{i,t+k} + l_{it}\, v_{it})}{2} \left( S_{i,t+k} - S_{it} \right) \right] \tag{B.1}$$

Dividing both sides of equation B.1 by $y_t$ gives the proportionate change in productivity attributable to each vehicle type.

The productivity improvement term may be further decomposed into separate average load and average utilisation components by a similar method. The physical productivity term, $l_{i,t+k} v_{i,t+k} - l_{it}\, v_{it}$, is equivalent to:

$$\frac{(l_{i,t+k} + l_{i,t})}{2} \left( v_{i,t+k} - v_{i,t} \right) + \frac{(v_{i,t+k} + v_{i,t})}{2} \left( l_{i,t+k} - l_{i,t} \right)$$

Substituting this into equation B.1, the change in vehicle productivity is given by:

$$\Delta_k y_t = \sum_{i=1}^{N} \left[ \frac{(S_{i,t+k} + S_{it})}{2} \left\{ \frac{(l_{i,t+k} + l_{i,t})}{2} \left( v_{i,t+k} - v_{i,t} \right) \right. \right. \\ \left. + \frac{(v_{i,t+k} + v_{i,t})}{2} \left( l_{i,t+k} - l_{i,t} \right) \right\} \\ \left. + \frac{(l_{i,t+k} v_{i,t+k} + l_{it} l_{it})}{2} \left( S_{i,t+k} - S_{it} \right) \right] \tag{B.2}$$

# APPENDIX C
# Modelling road freight productivity growth

Road freight transport in Australia is undertaken by a variety of different heavy vehicle types. Rigid trucks operate predominantly in urban areas. Articulated trucks are predominantly used for long-haul freight movements, but also carry a significant and increasing share of freight in urban areas. The share of road freight carried by articulated trucks increased appreciably with the introduction of reforms permitting general network access for larger and heavier vehicle combinations. Similarly, since their introduction approximately two decades ago, B-doubles' share of total road freight has grown such that by 2007 they accounted for approximately half of total articulated truck freight.

Understanding the impact of past regulatory changes on heavy vehicle use can help inform analysis of future alternative policy options. As far as BITRE is aware, no analysis has previously been undertaken that quantitatively estimates the impact of regulatory changes on heavy vehicle usage in Australia.[20]

This appendix presents in more detail the empirical specification and estimation results for several alternative generalised extreme value (GEV) models that relate trends in heavy vehicle freight share to changes in heavy vehicle operating costs and heavy vehicle regulations.

A separate simple linear relation, outlined in Section C.5, links changes in heavy vehicle freight shares and growth in average heavy vehicle loads across all rigid and articulated trucks. Combined together, the freight share model and freight share – average load relationship provide a tool for projecting likely future trends in heavy vehicle average loads.

## C.1 GEV model of heavy vehicle freight shares

The GEV model specification encompasses a family of predictive share-based models that provide a wide range of substitution responses (Train 2003). The MNL model is the most commonly known and simplest member of the GEV family. The NL model is the most widely used GEV model. Other members of GEV class of models include the PCL and overlapping nested logit (ONL) models.

GEV models are typically used to estimate choice probabilities using discrete choice data, where the data relates to choices by individual decision makers. Typical transport-related applications include analysis of transport mode choice from household travel survey data.

20 As part of the Council of Australian Governments (COAG) Road Reform Plan, the NTC is currently managing a project that will use stated preference data to estimate the response of heavy vehicle operators to changes in heavy vehicle charges.

Share-based model specifications, like the GEV model, also naturally lend themselves to analysis of grouped data, where the data set comprises counts or proportions (market shares). The heavy vehicle freight share data used here comprises grouped market shares observed over time—often referred to as a grouped panel data set. Grouped panel data can be easily accommodated in the GEV specification, and lagged variables can be included in the model providing delineation of short- and long-run effects.

The general form of the GEV model is:

$$P_i = \frac{Y_i G_i}{G} \tag{C.1}$$

where $G = G(Y_1, \ldots, Y_J)$, $Y_i = e^{V_i}$ and $G_i = \partial G / \partial Y_i$ and $V_{it}$ represents the observed 'utility' of choosing alternative $i$.

## *Observed utility*

The road freight industry is highly competitive. Market concentration is low and relatively low start-up costs and readily transferable capital facilitate easy entry and exit. Consequently, there is considerable pressure on operators to minimise operating costs and, subject to customers' requirements, operators will tend to prefer the freight vehicle combination that minimises the cost of hauling freight. Shipment characteristics—e.g. commodity type, shipment size, total shipment volume and origin and destination—influence costs, with smaller trucks typically more cost effective for small consignments and low shipment volumes while larger trucks will generally be more cost effective for larger volumes and longer distance hauls. Variable vehicle operating costs, such as fuel, labour (driver wages), oil, tyres and vehicle maintenance costs, typically comprise well over half of total freight vehicle operating costs. In an ideal world, road freight operators would choose that freight vehicle type $i$ which provided the lowest cost means of transporting shipment $k$. That is, $C_{ik} < C_{jk}$ for all $i \neq j$, where $C_{ik}$ denotes the cost of transporting shipment $k$ using freight vehicle type $i$.

For the grouped panel data available for this analysis, shipment characteristic information was unavailable, and so the covariate information included in the model was limited to vehicle characteristics and vehicle operating costs.

For the GEV model, the probability that vehicle type $i$ is chosen, in preference to all other vehicle types, is the probability that the average cost $C_{it} = V_{it} + \varepsilon_{it}$ is less than the average cost of all other heavy vehicle types. The subscript, $t$, denotes time. Average costs are defined as the sum of observed, $V_{it}$, and unobserved (stochastic), $\varepsilon_{it}$, average cost components.

Observed average costs, in turn, are defined here as the sum of a vehicle specific constant, $\alpha_i$, and average variable vehicle operating costs, $c_{it}$ (equation C.2). The lagged freight share term, $\ln S_{i,t-1}$, is included to capture dynamic adjustment.

$$V_{it} = \alpha_i + \beta c_{it} + \phi \ln S_{i,t-1} \tag{C.2}$$

where $c_{it}$ is the average variable cost per tonne kilometre, defined as the average operating cost per vehicle kilometre, $c^*_{it}$, divided by an index of the carrying capacity, $z_{it}$, of each heavy vehicle type. The average per kilometre vehicle operating costs included in the model are fuel, labour and vehicle registration costs (equation C.3). Carrying capacity is defined as a linear function of

GML, HML and maximum allowable length (see equation C.4).

$$c_{it} = \frac{\left(c_{it}^{\text{Fuel}} + c_{it}^{\text{Labour}} + c_{it}^{\text{Registration}}\right)}{z_{it}} \tag{C.3}$$

$$z_{it} = \text{GML}_{it} + \gamma_{\text{Length}}\text{Length}_{it} + \gamma_{\text{HML}}\text{HML}_{it} \tag{C.4}$$

## Dynamic effects

Heavy vehicles are relatively long-lived capital assets and represent a significant capital investment for operators. Changes in the relative composition of the road freight task (e.g. mix of long-distance freight), and changes in truck costs and capabilities, will change the optimal mix of freight vehicles. However, the actual composition of the commercial vehicle fleet will take time to adjust as operators seek to optimise the sum of current and future discounted operating and capital costs. The lagged freight share term in equation C.2, $\phi \ln S_{i,t-1}$, will capture the dynamic adjustment of road freight shares to changes in observed factors.

# *Empirical model specifications*

Road vehicle type freight share model estimates were derived for three alternative empirical specifications:

- multinomial logit
- nested logit
- paired combinatorial logit

The functional form for each of these specifications is given below.

## MNL specification

In the MNL model, the probability of choosing vehicle type $i$ is:

$$P_{it} = \frac{e^{V_{it}}}{\sum_{j=1}^{N} e^{V_{jt}}} \tag{C.5}$$

As noted in the introduction, the MNL is the simplest form of GEV model and imposes particular restrictions on the range of substitutability between alternatives. In particular, the MNL model restricts the cross-elasticities to be identical across all alternatives. The practical effect of this restriction is that any change in market share of vehicle type $i$, resulting from a change in some attribute of $i$, will be drawn equally from across all other alternatives.

## NL specification

The nested logit model specification is appropriate when the set of available options can be partitioned into several subsets (or nests $k$), such that the options within each subset have relatively similar characteristics but are relatively different between subsets.

In the NL model the probability of selecting alternative $i$, belonging to nest $k$ is:

$$P_{it} = \frac{e^{V_{it}/\lambda_k} \left( \sum_{j \in B_k} e^{V_{jt}/\lambda_k} \right)^{\lambda_k - 1}}{\sum_{l=1}^{K} \left( e^{V_{jt}/\lambda_l} \right)^{\lambda_l}} \qquad \text{(C.6)}$$

The nested logit specification may be decomposed into separate marginal ($P_{B_k t}$) and conditional probabilities ($P_{it|B_k}$) such that:

$$P_{it} = P_{it|B_k} P_{B_k t} \qquad \text{(C.7)}$$

where the marginal probability ($P_{B_k t}$) is the probability of choosing next $B_k$:

$$P_{B_k t} = \frac{e^{W_{kt} + \lambda_k IV_{kt}}}{\sum_{l=1}^{K} e^{W_{lt} + \lambda_l IV_{lt}}}$$

and the conditional probability ($P_{it|B_k}$) represents the probability of selecting alternative $i$ within nest $B_k$:

$$P_{it|B_k t} = \frac{e^{V_{it}/\lambda_k}}{\sum_{j \in B_k} e^{V_{jt}/\lambda_k}} \qquad \text{(C.8)}$$

and $IV_{kt}$ is the inclusive value of sub-nest $k$—the log-sum of all alternatives in nest $k$:

$$IV_{kt} = \ln \sum_{j \in B_k} e^{V_{jt}/\lambda_k} \qquad \text{(C.9)}$$

Nests containing a single alternative are called *degenerate* nests. The inclusive value parameter ($\lambda_k$) cancels out of the choice probability for degenerate nests. Inclusive value parameter estimates greater than one imply that the nesting structure is inconsistent with the random utility model (RUM) and that alternatives within the nest should not share the nest.

For more than a small number of alternatives, the number of possible nesting options is large. Two alternative NL specifications were estimated:

- a 'three-branch' nesting specification, comprising separate LCV, rigid trucks and articulated truck nests
- a 'four-branch' nesting specification, comprising LCVs, rigid trucks, general access articulated trucks (i.e. single trailer articulated trucks and B-doubles) and 'restricted-access' articulated truck (i.e. road trains and 'other' articulated trucks) nests. This nesting structure was chosen because it more readily lends itself to simulating the potential impacts of future growth in large road train alternative heavy vehicles, such as B-triples and AB-triples.

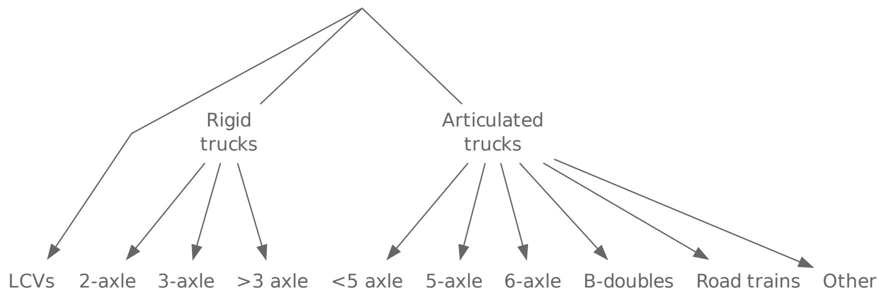
These are illustrated in Figure C.1.

## PCL specification

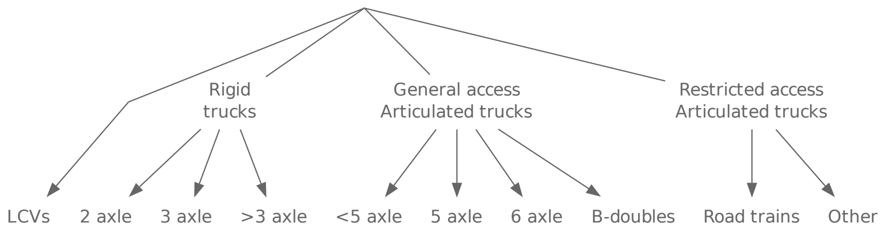
The PCL specification is a more general form from among the GEV family. In the PCL specification, each pair of alternatives is specified as a separate nest. The probability of choosing alternative $i$ in the PCL specification is:

$$P_{it} = \frac{\sum_{j \neq i} e^{V_{it}/\lambda_{ij}} \left( e^{V_{it}/\lambda_{ij}} + e^{V_{jt}/\lambda_{ij}} \right)^{\lambda_{ij} - 1}}{\sum_{k=1}^{J-1} \sum_{l=k+1}^{J} \left( e^{V_{kt}/\lambda_{kl}} + e^{V_{lt}/\lambda_{kl}} \right)^{\lambda_{kl}}} \qquad \text{(C.10)}$$

FC.1 Nesting specifications




(a) Three-branch nesting structure




(b) Four-branch nesting structure

The $\lambda_{ij}$ parameters indicate the degree of independence between alternatives $i$ and $j$. Equivalently, $1 - \lambda_{ij}$ is a measure of the correlation between the unobserved utility of alternatives $i$ and $j$. The PCL model allows for a wider range substitution responses amongst alternatives than either the MNL or NL specifications. Koppelman and Wen (2000) note that the maximum number of $\lambda_{ij}$ parameters that can be estimated in the PCL model is $J(J-1)/2 - 1$, and it is necessary to impose at least one restriction on the $\lambda_{ij}$'s. If $\lambda_{ij} = 1$ for all $i$ and $j$, the PCL is identical to the MNL specification. The PCL specification can also reflect any NL specification through the choice of appropriate restrictions on the $\lambda_{ij}$'s.

## *A dynamic market diffusion interpretation*

The inclusion of the lagged freight share term in the observed utility term means the model may also be interpreted as a dynamic market diffusion process, similar in form to the logistic substitution model (Marchetti and Nakicenovic 1979, Gruebler 1990, Kwasnicki and Kwasnicka 1996).

The logistic substitution model is a simple dynamic specification for modelling market shares of competing products or technologies over time. The model partitions the life cycle of competitors into three distinct phases: growth, saturation and decline. The logistic substitution equations are recursive formulae in which the change in product/technology share is a function of the prevailing share and the relative 'competitiveness' (or 'attractiveness') of each product/technology (equation C.14).

$$S_{k,t+1} = \frac{c_k}{\sum_m c_m S_{m,t}} S_{k,t} \tag{C.11}$$

where

$c_k$ is the competitiveness index of product/technology $k$

$S_{k,t}$ is the market share of product/technology $k$ at time $t$.

In the simple logistic substitution model, the competitiveness indexes are constant and it is the introduction of new 'superior' products/technologies that drives the growth, saturation and decline life cycle. BITRE has used the simple logistic substitution model to project future mode share trends for long-distance passenger travel and freight movements (see BITRE (2008), BTRE (2006)).

The logistic substitution model can be easily re-interpreted as a standard multinomial logit model, where the competitiveness indices are a function of the attributes of the different alternatives, and can vary over time. Letting $c_{kt} = e^{V_{kt}}$, the logistic substitution model becomes:

$$S_{k,t+1} = \frac{e^{V_{kt} + \ln S_{k,t}}}{\sum_m e^{V_{mt} + \ln S_{m,t}}} = \frac{e^{V_{kt}}}{\sum_m e^{V_{mt}} S_{m,t}} S_{k,t} \tag{C.12}$$

This specification is similar to equation C.5, after substituting equation C.2 for $V_{it}$, with the restriction $\phi_i = 1$ for all $i$. This restriction also gives rise to the logistic substitution model's propensity to produce a single dominant alternative—that is, in the prolonged absence of a new technology the dominant technology's market share will continue to grow asymptotically towards 100 per cent.[21] While this specification will be fine in certain markets, it is not appropriate for modelling road freight market shares since different vehicle types service different segments of the overall freight market, so no single heavy vehicle type is likely to ever carry close to 100 per cent of all road freight.

Where $\phi < 1$, the updating function can be re-interpreted as:

$$S_{k,t+1} = \frac{e^{V_{kt}} S_{k,t-1}^{\phi-1}}{\sum_m e^{V_{mt}} S_{m,t-1}^{\phi-1} S_{m,t}} S_{k,t-1} \tag{C.13}$$

Now the competitiveness indices are a function of the observed utility and the existing mode share:

$$c_{k,t} = e^{V_{kt}} S_{k,t-1}^{\phi-1} \tag{C.14}$$

For $\phi < 1$ the dynamic logit specification no longer has the undesirable property of increasing dominance by one alternative. Instead, the size of the $S_{i,t-1}^{\phi-1}$ term declines as $S_{i,t-1}$ increases, reducing the competitiveness of alternative $i$, and the competitiveness index declines as $\phi$ approaches one.

## *Elasticity estimates*

The impact of changes in costs and regulatory factors on road freight vehicle shares can be predicted using elasticities derived from the GEV models. The GEV model elasticities show the proportionate response in freight share to a change in cost or other factor.

21 With $\phi_i = 1$, observed utility $(V_{it})$ will grow without bound and the most 'competitive' technology—that is with the highest $V_{it}$—will dominate.

## Cost elasticities

The direct- and cross-elasticities for each of the MNL, NL and PCL with respect to a change in cost are shown in Table C.1.

**TC.1** Operating cost direct- and cross-elasticities, selected GEV model specifications

| Model | Direct-elasticity | Cross-elasticity |
|---|---|---|
| MNL | $\beta c_{it}(1 - S_{it})$ | $-\beta c_{kt} S_{kt}$ |
| NL | $\beta c_{it}\left[\frac{1}{\lambda_k} - \frac{1-\lambda_k}{\lambda_k} S_{it\|B_k} - S_{it}\right]$ | $-\beta c_{jt}\left[\frac{1-\lambda_k}{\lambda_k} S_{it\|B_k} + S_{jt}\right]$ for $i \neq j,\ j \in k$<br>$-\beta c_{jt} S_{jt}$ for $i \neq j,\ j \notin k$ |
| PCL | $\left\{\sum_{j \neq i} \frac{S_{ij} S_{i\|ij}}{S_i}\left[\frac{1-(1-\lambda_{ij})S_{i\|ij}}{\lambda_{ij}}\right] - S_{it}\right\}\beta c_{it}$ | $-\left\{S_{it} + \left(\frac{1-\lambda_{ij}}{\lambda_{ij}}\right)\frac{S_{ij} S_{i\|ij} S_{j\|ij}}{S_{jt}}\right\}\beta c_{it}$ |

The direct-elasticities for both the NL and PCL models will be greater than the equivalent MNL model direct elasticity, for alternatives within an NL nest or where the independence parameter $\lambda_{ij}$ is less than one between any pair of alternatives in the PCL model. As noted earlier, the MNL model cross-elasticities depend entirely on the probability of the alternative mode, whereas the cross-elasticities of the NL and PCL models are more complex. For the NL model, the cross-elasticities of alternatives within the same nest are larger than for other alternatives. The cross-elasticities for alternatives outside the nest are identical to the MNL model cross-elasticities. PCL model cross-elasticities are more complex again, but will be larger between alternatives for which the independence parameter ($\lambda_{ij}$) is less than one.

Note that the elasticities here refer to the *percentage change in market share* in response to a change in $X_{m \cdot t}$. The absolute change in market share (in percentage point terms) is derived by multiplying the own- and cross-effect elasticities by vehicle type $i$'s freight share.

## Regulatory effects

Truck capacity and regulatory factors enter the model specification either directly, as a factor influencing average operating costs per vehicle kilometre, or through the capacity term. For regulatory factors that influence costs directly, such as regulated speed limits and driving hours, the direct- and cross-elasticities will be equal to the cost elasticities, shown in Table C.1, times the proportionate change in the factor and the relevant operating cost share. For factors that enter the model through the capacity term, the elasticities will be equal to the relevant cost elasticity (denoted by $\eta_{ij}$ in Table C.2) multiplied by the proportionate change in capacity-related variable. The capacity-related elasticities for each of GML, HML and maximum allowable vehicle length are shown in Table C.2.

**TC.2** Vehicle capacity related direct- and cross-elasticities, selected GEV model specifications

| Factor | Direct-elasticity | Cross-elasticity |
|---|---|---|
| GML | $-\eta_{ii}\frac{\text{GML}_{it}}{z_{it}}$ | $-\eta_{ik}\frac{\text{GML}_{kt}}{z_{kt}}$ |
| Length | $-\eta_{ii}\gamma_{\text{Length}}\frac{\text{Length}_{it}}{z_{it}}$ | $-\eta_{ik}\gamma_{\text{Length}}\frac{\text{Length}_{kt}}{z_{kt}}$ |
| HML | $-\eta_{ii}\gamma_{\text{HML}}\frac{\text{HML}_{it}}{z_{it}}$ | $-\eta_{ik}\gamma_{\text{HML}}\frac{\text{HML}_{kt}}{z_{kt}}$ |

Note: $\eta_{ij}$ denotes the relevant cost elasticity from Table C.1.

### Dynamic effects

The inclusion of the lagged freight share terms in the model specification allows differentiation between short- and long-term effects. The elasticities listed in Tables C.1 and C.2 are the short-term elasticities. Their long-term counterparts are derived by simply multiplying the short-term elasticities by $(1-\phi)^{-1}$. For example, the long-term own-cost elasticity is given by:

$$\eta_{ii}^{LR} = \frac{\eta_{ii}^{SR}}{(1-\phi)} \tag{C.15}$$

## C.2 Data

The majority of the data used in the analysis was sourced from the Australian Bureau of Statistics (ABS) Survey of Motor Vehicle Use (SMVU). In particular, heavy vehicle freight shares, average fuel efficiency and average VKT are sourced from the SMVU (ABS 2008, and earlier issues). Limitations in the SMVU data required some adjustments to the data in order to undertake the analysis.

The SMVU was undertaken more or less triennially between 1971 and 1998 and annually between 1998 and 2007, and provides 17 observations spanning the 36-year period between 1971 and 2007. For the analysis, road freight shares, and other SMVU-sourced data, were interpolated using Stineman (1980) interpolation to provide annual time series between 1971 and 2007.

The SMVU estimates are derived from a sample survey of vehicle use. At the level of the ten freight vehicle classes considered for the analysis, the standards errors are relatively large, especially since 1991 following reductions in the sample size. Consequently, there is significant inter-sample variation in estimated freight shares, which, left unadjusted, has a significant impact on the parameter estimates in the dynamic model specification. The SMVU freight share estimates were smoothed to mitigate the impact of inter-sample variation on the parameter estimates. The smoothing procedure generally only affected the input freight shares between 1995 and 2007.

Heavy vehicle operating costs and regulatory covariate data—mass and dimensions limits, vehicle speed limits, driving hours and heavy vehicle registration charges—were derived from the following sources:

- Average per kilometre vehicle fuel costs are the product of average fuel consumption by vehicle type, sourced from the SMVU, and real average fuel costs. Diesel fuel prices were not available pre-1995, and movements in petrol fuel prices were used as a proxy. Changes in heavy vehicle fuel-based road user charges since 2001 were explicitly included in average fuel costs.
- Average per kilometre labour costs were defined as the hourly wage rate divided by the travel-weighted average of urban and non-urban travel speeds. The increase in maximum allowable travel speeds for heavy vehicles outside urban areas in the mid-1980s significantly reduced the average labour cost per vehicle kilometre for those vehicle classes.
- Average per kilometre registration charges are equal to real heavy vehicle registration charges divided by average VKT, for each vehicle class. Since 1992 heavy vehicle registration charges have been determined nationally. Prior to 1992 heavy vehicle registration charges were set separately by each state and territory. The pre-1992 registration charges used in the analysis are an approximate traffic-weighted average across the different jurisdictions. Average VKT for each vehicle class was sourced from the SMVU.

- Heavy vehicle mass and dimension limits were sourced from a variety of published reports into heavy vehicle regulation and pricing, including: NAASRA (1976), NAASRA (1985), ISC (1990), NTC (2009b) and NTC (2008).

Annual data was generally not available for each of these variables. In all cases where annual data was not available, the available data was interpolated to derive annual series' using the Stineman (1980) interpolation method.

## C.3 Estimation

All estimates were derived via full information maximum likelihood (FIML) estimation using R—the free software environment for statistical analysis and graphics (Ihaka and Gentleman 1996). Maximum likelihood estimates are both consistent and efficient. The log-likelihood function used to estimate heavy vehicle freight shares was:

$$\ln L = \sum_{t} \sum_{i} S_{it} \ln P_{it} \qquad \text{(C.16)}$$

where $S_{it}$ is the observed freight share carried by heavy vehicle type $i$ and $P_{it}$ is the probability choosing vehicle type $i$. The calculated standard errors are based on the asymptotic (or robust) covariance matrix (see Train 2003, p. 205).

## C.4 Empirical results

The maximum likelihood estimate (MLE) results for the simple MNL model, two NL specifications—the three branch NL specification and the four-branch NL specification—and the preferred PCL model specification are shown in Table C.3.

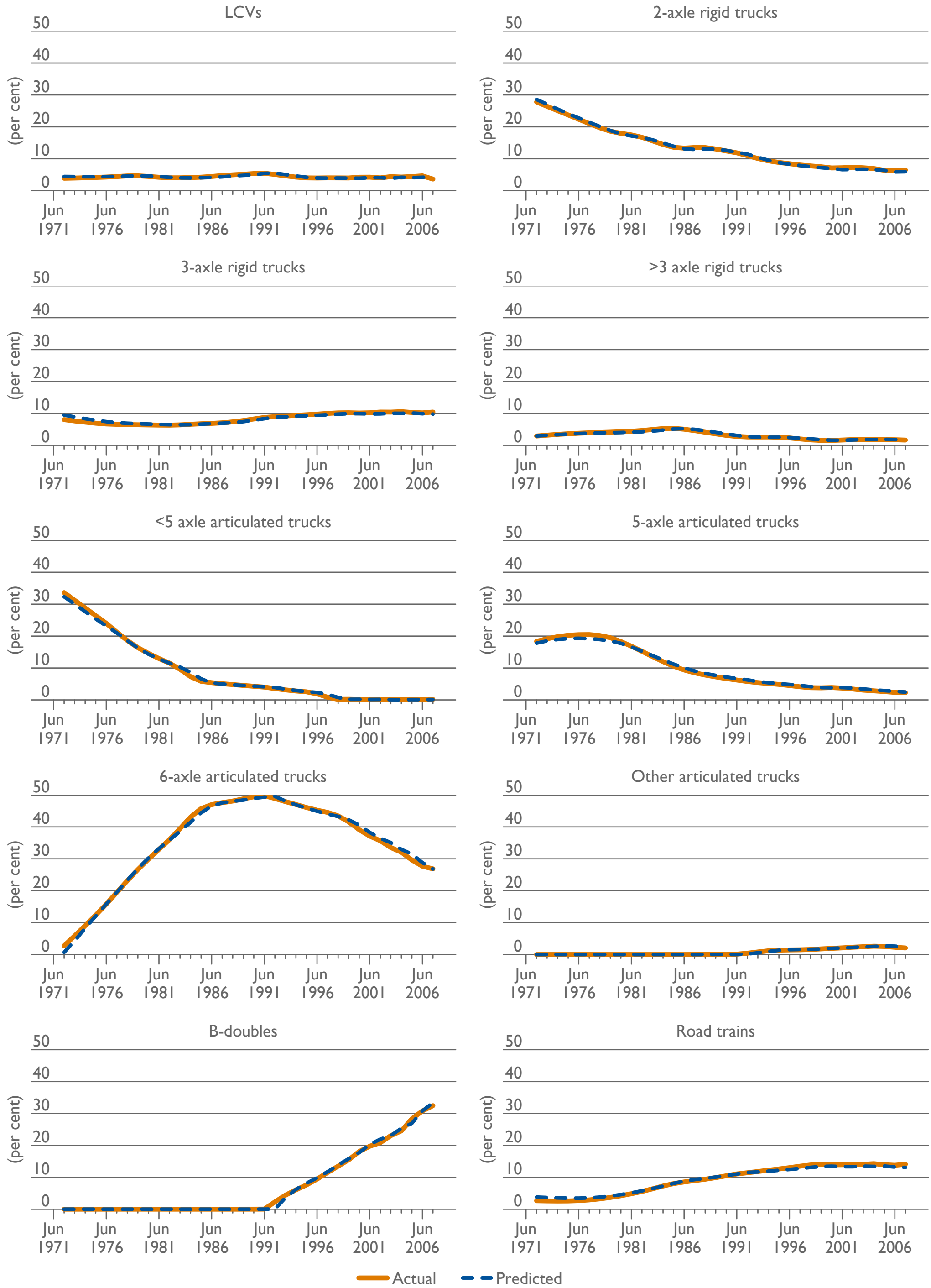
Figure C.2 shows the actual and predicted freight shares, by vehicle type and axle configuration between 1971 and 2007 for the preferred PCL model specification. It may be observed that the model predictions match the actual freight shares very closely across most of the observation period, 1971 to 2007. In particular, the model captures the both the initial increase and subsequent reduction in freight share of five- and six-axle articulated trucks, the gradual reduction in freight share of two-axle rigid and four-axle articulated trucks, and the rapid uptake of B-doubles, albeit with a slight lag. The MNL and NL specifications fit the observed heavy vehicle freight shares almost equally as well as the PCL specification.

Considering the parameter estimates, listed in Table C.3, the lagged share parameter terms ($\phi$) are all statistically significant and the estimates are relatively similar across each of the alternative model specifications. The size of the lagged share parameter estimate—0.74 for the three-branch NL specification and between 0.81 and 0.90 for the other specifications—implies a reasonable lag in market response to changes in heavy vehicle regulations and technology.[22]

The inclusive value parameters for rigid and articulated trucks in the NL specifications are statistically significant. Several of the independence parameter estimates in the PCL model are also statistically different from 1, providing a richer correlation structure than the MNL specification. The NL and PCL specifications all produce higher log-likelihood values than the equivalent MNL specification.

22 A lagged share parameter estimate of 0.60 implies the time to 50 per cent of the full adjustment is 0.35 years and a lagged share parameter estimate of 0.90 implies the 5.5 years to 50 per cent of full adjustment.

## FC.2 Actual and predicted road freight shares, by vehicle type and axle configuration, 1971–2007




Sources: BITRE estimates.

## TC.3 Nested logit heavy vehicle freight share model results

| | Model specifications | | | |
|---|---|---|---|---|
| | MNL | Three-branch NL | Four-branch NL | PCL[b] |
| **Specific constants** | | | | |
| Two-axle rigid trucks | 0.0183<br>(1.501e−05) | 0.3679<br>(2.142e−04) | 0.134<br>(3.165e−05) | 0.07612<br>(4.843e−03) |
| Three-axle rigid trucks | 0.0379<br>(1.503e−05) | 0.3987<br>(2.288e−04) | 0.1871<br>(3.207e−05) | 0.1179<br>(0.0064) |
| Four-axle rigid trucks | −0.0876<br>(1.388e−05) | 0.3824<br>(2.365e−04) | 0.1607<br>(3.596e−05) | 0.06096<br>(0.0062) |
| Four-axle articulated trucks | −0.0722<br>(1.62e−05) | 0.3986<br>(2.401e−04) | 0.006704<br>(3.765e−05) | 0.02995<br>(0.0060) |
| Five-axle articulated trucks | −0.0097<br>(1.669e−05) | 0.4606<br>(2.462e−04) | 0.06737<br>(3.754e−05) | 0.1129<br>(0.0065) |
| Six-axle articulated trucks | 0.2149<br>(1.704e−05) | 0.6644<br>(2.516e−04) | 0.2967<br>(3.727e−05) | 0.3016<br>(0.0039) |
| B-doubles | −7.503e−05<br>(3.729e−0) | 0.5007<br>(2.434e−04) | 0.06903<br>(4.036e−05) | −0.05299<br>(0.0075) |
| Road trains | 0.2921<br>(1.599e−05) | 0.7414<br>(2.590e−04) | 0.369<br>(3.688e−05) | 0.3932<br>(0.0077) |
| Other articulated trucks | 0.1013<br>(1.605e−05) | 0.5718<br>(2.629e−04) | 0.1251<br>(2.603e−05) | 0.09767<br>(0.0053) |
| **Dependent variables** | | | | |
| Average cost | −0.03835<br>(8.197e−05) | −0.1111<br>(8.760e−04) | −0.04302<br>(5.649e−05) | −0.02216<br>(0.0045) |
| Length | −0.2362<br>(3.04e−04) | −0.2543<br>(0.0016) | −0.2319<br>(7.98e−05) | −0.2513<br>(0.0081) |
| HML | 0.1259<br>(0.0017) | 0.5277<br>(0.0041) | 0.1249<br>(5.770e−04) | 0.08817<br>(0.0088) |
| $\phi$ | 0.8987<br>(1.117e−06) | 0.7364<br>(3.97e−07) | 0.8662<br>(6.531e−06) | 0.8117<br>(0.0017) |
| **Dummy variables** | | | | |
| B doubles | −0.5454<br>(5.113e−05) | −0.2213<br>(0.0056) | −0.5677<br>(1.996e−04) | −0.6423<br>(0.0111) |
| Other articulated trucks | 0.0678<br>(4.271e−05) | 0.0261<br>(9.991e−05) | 0.0231<br>(4.745e−04) | 0.09736<br>(0.01399) |
| **Inclusive value parameters** | | | | |
| LCVs | .. | .. | 1 | .. |
| Rigid trucks | .. | 0.7428<br>(5.565e−07) | 0.8725<br>(8.721e−06) | .. |
| GA articulated trucks | .. | 0.8199<br>(2.444e−06) | 0.9716<br>(6.63e−06) | .. |
| RA articulated trucks | .. | .. | 1 | .. |
| **Summary statistics** | | | | |
| $\ln L$ | −63.5129 | −63.4970 | −63.5085 | −63.5025 |
| No. parameters | 15 | 17 | 17 | 27 |

.. Not applicable.
a. Maximum likelihood estimates. Standard errors in parentheses, derived from the robust covariance matrix (Train 2003).
b. The PCL model independence parameter set and estimates are: LCV:Rig2A - 1; Rig2A:Rig3A - 0.2871 (6.846e-05); Rig3A:Rig4A - 0.3901 (0.0014); Rig4A:Art4A - 0.3265 (0.0019); Art4A:Art5A - 0.284 (0.0010); Art5A:Art6A - 0.3454 (1.907e−04); Art6A:ArtOt - 1; Art6A:ArtBd - 0.2293 (0.0022); Art6A:ArtRt - 1; ArtOt:ArtBd - 1; ArtBd:ArtRt - 1; Other - 0.8551 (0.0034).
Source: BITRE estimates.

The signs of the explanatory variable parameter estimates are generally as expected. The average cost parameter estimate is negative across all model specifications, implying that an increase in the average cost of truck type $i$ reduces its freight share. Freight shares are positively correlated with increased GML and HML. Somewhat surprisingly, the estimates imply that freight shares are negatively correlated with maximum length limits.

Table C.4 shows, for each commercial vehicle class, the long-run direct elasticities with respect to average cost calculated using the mean share and average cost estimates. The results imply that vehicle type choice is quite inelastic with respect to average cost—in other words, small

## TC.4 Long-run direct average cost elasticity estimates

| | Model specification | | | |
|---|---|---|---|---|
| Vehicle type | MNL | Three-branch NL | Four-branch NL | PCL |
| LCVs | −0.244 | −0.177 | −0.211 | −0.1661 |
| 2-axle rigid trucks | −0.027 | −0.015 | −0.020 | −0.0078 |
| 3-axle rigid trucks | −0.019 | −0.012 | −0.014 | −0.0095 |
| >3 axle rigid trucks | −0.017 | −0.011 | −0.013 | −0.0264 |
| <5 axle articulated trucks | −0.013 | −0.008 | −0.011 | −0.0076 |
| 5-axle articulated trucks | −0.010 | −0.006 | −0.009 | −0.0046 |
| 6-axle articulated trucks | −0.007 | −0.003 | −0.006 | 0.0004 |
| B-doubles | −0.011 | −0.007 | −0.009 | −0.0581 |
| Road trains | −0.008 | −0.005 | −0.007 | −0.0095 |
| Other articulated trucks | −0.004 | −0.002 | −0.003 | −0.0016 |

Source: BITRE estimates.

changes in costs have very little impact on vehicle type choice. The NL and PCL model elasticity estimates are generally less elastic (i.e. smaller in absolute value) than the MNL elasticities. The freight share of larger freight vehicle configurations tends to be less elastic than for smaller freight vehicles.

Table C.5 shows the long-run direct elasticities with respect to GML, maximum length and HML, again calculated using the mean shares and attribute values for each heavy vehicle class. Again, the results imply that vehicle type choice is quite inelastic with respect to changes in capacity variables, the NL and PCL model elasticity estimates are generally less elastic (i.e. smaller in absolute value) than the MNL elasticities, and the freight share of larger freight vehicle configurations tends to be less elastic than for smaller freight vehicles. The estimates also imply that changes in GML have a proportionately larger impact on freight shares than changes in the maximum allowable length or changes in HML.

# C.5 Average heavy vehicle loads and freight shares

This section provides some additional detail on the process used to convert freight shares into average loads, discussed in Chapter 3.

Average vehicle loads are defined as total freight tonne kilometres divided by total vehicle kilometres travelled (VKT). The fleet-wide average load, $\overline{L}$, is defined as the VKT-weighted sum of the average load for each heavy vehicle class:

$$\overline{L} = \sum_i \frac{\mathrm{VKT}_i \overline{L}_i}{\sum_j \mathrm{VKT}_j} \tag{C.17}$$

Letting $S_i^*$ be the tonne kilometre share of vehicle class $i$, then $\mathrm{VKT}_i$ is:

$$\mathrm{VKT}_i = \frac{S_i^* \mathrm{TKM}}{\overline{L}_i} \tag{C.18}$$

Substituting equation C.18 into C.17 and rearranging provides the following relationship between fleet average load, vehicle class average loads and freight tonne kilometre shares:

$$\overline{L}^{-1} = \sum_i \frac{S_i^*}{\overline{L}_i} \tag{C.19}$$

## TC.5 Long-run direct capacity-related elasticity estimates

| | Model specification | | | |
|---|---|---|---|---|
| Vehicle type | MNL | Three-branch NL | Four-branch NL | PCL |
| **GML** | | | | |
| LCVs | 0.646 | 0.247 | 0.535 | 0.3775 |
| 2-axle rigid trucks | 0.040 | 0.015 | 0.029 | 0.0126 |
| 3-axle rigid trucks | 0.024 | 0.010 | 0.018 | 0.0124 |
| >3 axle rigid trucks | 0.020 | 0.009 | 0.015 | 0.0322 |
| <5 axle articulated trucks | 0.016 | 0.007 | 0.014 | 0.0101 |
| 5-axle articulated trucks | 0.012 | 0.005 | 0.010 | 0.0056 |
| 6-axle articulated trucks | 0.008 | 0.003 | 0.006 | −0.0004 |
| B-doubles | 0.012 | 0.006 | 0.010 | 0.0694 |
| Road trains | 0.009 | 0.004 | 0.008 | 0.0052 |
| Other articulated trucks | 0.004 | 0.002 | 0.004 | 0.0020 |
| **Maximum length** | | | | |
| LCVs | −0.483 | −0.188 | −0.387 | −0.2412 |
| 2-axle rigid trucks | −0.018 | −0.007 | −0.013 | −0.0058 |
| 3-axle rigid trucks | −0.007 | −0.003 | −0.005 | −0.0038 |
| >3 axle rigid trucks | −0.005 | −0.002 | −0.004 | −0.0083 |
| <5 axle articulated trucks | −0.005 | −0.002 | −0.004 | −0.0033 |
| 5-axle articulated trucks | −0.003 | −0.001 | −0.002 | −0.0015 |
| 6-axle articulated trucks | −0.002 | −0.001 | −0.001 | 0.0001 |
| B-doubles | −0.003 | −0.001 | −0.002 | −0.0169 |
| Road trains | −0.002 | −0.001 | −0.002 | −0.0011 |
| Other articulated trucks | −0.001 | 0.000 | −0.001 | −0.0005 |
| **HML** | | | | |
| LCVs | 0.080 | 0.117 | 0.064 | 0.0298 |
| 2-axle rigid trucks | 0.005 | 0.007 | 0.003 | 0.0010 |
| 3-axle rigid trucks | 0.003 | 0.005 | 0.002 | 0.0010 |
| >3 axle rigid trucks | 0.002 | 0.004 | 0.002 | 0.0026 |
| <5 axle articulated trucks | 0.002 | 0.003 | 0.002 | 0.0008 |
| 5-axle articulated trucks | 0.001 | 0.002 | 0.001 | 0.0004 |
| 6-axle articulated trucks | 0.001 | 0.001 | 0.001 | 0.0000 |
| B-doubles | 0.002 | 0.003 | 0.001 | 0.0057 |
| Road trains | 0.001 | 0.002 | 0.001 | 0.0004 |
| Other articulated trucks | 0.001 | 0.001 | 0.000 | 0.0002 |

Source: BITRE estimates.

Equation C.19 can be used to predict heavy vehicle average loads for all rigid trucks and articulated trucks.

# C.6 Forecasting future heavy vehicle productivity trends

In Chapter 4, the model results are used to predict likely future heavy vehicle productivity growth for three future scenarios:

- a 'no further regulatory change' scenario
- a 'minimal IAP/PBS network access' scenario—that is, use of B-triples, AB-triples and BAB-quad heavy vehicle types on road train routes
- an 'extended IAP/PBS network access' scenario—that is, B-triples operating on B-double routes and AB-triple, BAB-quad heavy vehicle types operating on road train routes.

and three alternative scenarios:

- no B-doubles counterfactual
- increase in GML (ten per cent)

- increase in real B-double registration charges.

The following section outlines the assumptions underpinning those scenarios.

## *No further regulatory change*

In this scenario, most regulatory settings are assumed to remain unchanged over the forecast horizon. In particular, GML and HML mass limits and vehicle length limits are assumed to remain at 2007 levels. Real heavy vehicle registration charges are assumed to remain constant at 2010 levels. The fuel efficiency of heavy vehicles is assumed to improve by approximately 0.5 per cent per annum. Driving hour regulations and legislated heavy vehicle speeds are also assumed to remain unchanged over the forecast horizon.

## *Minimal IAP/PBS network access scenario*

This scenario models the impact of B-triple and AB-triple access on road train routes on future truck-specific freight shares and fleet average loads. The modelled scenario assumed AB-triple mass limits of 102.5 tonnes under GML, 104.5 tonnes under CML and 113.0 tonnes under HML, and a maximum allowable length of 36.5 metres. AB-triple annual vehicle registration charges were $17 542 in 2010, and are assumed to remain constant in real terms over the forecast horizon. The average fuel efficiency of AB-triples is assumed to be between that of B-doubles and road trains. B-triples are not included among the available heavy vehicle combinations in this scenario. The average cost and regulatory settings for all other vehicles types are assumed to remain unchanged from 2010 onwards.

## *Extended IAP/PBS network access scenario*

This scenario models the impact of B-triple access to existing B-double routes and AB-triple and BAB-quad heavy vehicle access to existing road train routes on future truck-specific freight shares and fleet average loads. The modelled scenario assumes B-triple mass limits of 82.5 tonnes under GML, 84.5 tonnes under CML and 90.5 tonnes under HML, and a maximum allowable length of 36.5 metres. B-triple annual vehicle registration charges were approximately $21 712 in 2010, and is assumed to remain constant, in real terms, over the forecast horizon. The average fuel efficiency of B-triples is assumed to be between that of B-doubles and road trains, and lower than that of AB-triples.

AB-triple mass limits, length limits and annual vehicle registration charges are as per the IAP/PBS minimal impact scenario. The average cost and regulatory settings for all other vehicles types are assumed to remain unchanged from 2010 onwards.

## *No B-doubles counterfactual*

The no B-doubles counterfactual scenario estimates the relative heavy vehicle freight shares to 2007 if B-doubles had not been introduced in the late 1980s, and the implications for average vehicle loads. The scenario is modelled by extending the B-double dummy variable to cover the entire period 1971 to 2007.

## *Ten per cent increase in GMLs*

This scenario is modelled by assuming that GML are: (i) 10 per cent; and (ii) 20 per cent higher from 2011 onwards for every heavy vehicle type. All other variables are held constant at 2007 or, in the case of mass limits and vehicle registration charges, 2010 values. Even though actual fuel consumption rates might be expected to increase slightly in response to higher average loads, for simplicity average fuel consumption rates are assumed to remain unchanged across all vehicle classes.

# Abbreviations

**ABS** Australian Bureau of Statistics
**ACT** Australian Capital Territory
**AFM** advanced fatigue management
**ATAC** Australian Transport Advisory Council
**ATC** Australian Transport Council
**BFM** basic fatigue management
**BITRE** Bureau of Infrastructure, Transport and Regional Economics
**CML** Concessional Mass Limits
**COAG** Council of Australian Governments
**CPI** Consumer Price Index
**CVP** Continuous Voyage Permits
**ERVL** Economics of Road Vehicle Limits
**ESA** equivalent standard axle
**FIML** full information maximum likelihood
**FIRS** Federal Interstate Registration Scheme
**GDP** gross domestic product
**GEV** generalised extreme value
**GML** General Mass Limits
**GVM** gross vehicle mass
**HML** Higher Mass Limits
**IAP** Intelligent Access Program
**km** kilometre
**LCV** light commercial vehicle
**MLE** maximum likelihood estimate
**MNL** multinomial logit
**nes** not elsewhere specified
**NL** nested logit

**NLTN** National Land Transport Network

**NSW** New South Wales

**NTC** National Transport Commission

**NT** Northern Territory

**OD** origin–destination

**ONL** overlapping nested logit

**pa** per annum

**PBS** Performance Based Standards

**PCL** paired combinatorial logit

**Qld** Queensland

**RoRVL** Review of Road Vehicle Limits

**RUM** random utility model

**SA** South Australia

**SMVU** Survey of Motor Vehicle Use

**SVP** Single Voyage Permits

**TIC** Truck Industry Council

**TKM** tonne kilometre

**Tas.** Tasmania

**Vic.** Victoria

**VKT** vehicle kilometres travelled

**WA** Western Australia

**WIM** weigh-in-motion

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