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Trends in non-urban road freight using weigh-in-motion (WIM) data

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Abstract

Accurate, up-to-date and reasonably detailed freight movements data is crucial for informed policy analysis, freight transport modelling and infrastructure investment evaluation. However, the breadth and diversity of road freight industry activity means detailed road data is typically very costly to collect. Consequently, comprehensive road freight data collections have been infrequent and restricted in scope to limit costs. Administrative data sources, such as weigh-in-motion (WIM) site data, can provide additional data about road freight activity that complements survey-based collections.

This paper describes current Bureau of Infrastructure, Transport and Regional Economics (BITRE) research to develop trend indicators of road freight movements on Australia's major intercapital road corridors using state and territory road agency WIM site data. The preliminary results show the strong growth in road freight movements on Australian intercapital corridors over the last 15 years and the significance of B-double uptake in facilitating intercapital road freight growth.

1. Introduction

Accurate, up-to-date and reasonably detailed freight movements data is crucial for informed policy analysis, freight transport modelling and infrastructure investment evaluation. Collection of reliable and comprehensive road freight statistics has traditionally relied on large sample survey methods to adequately and accurately capture the diverse and dispersed nature of road freight activity. Survey-based collections, however, are very expensive, especially for origin–destination (OD) level survey data, and there are usually considerable time lags between activity, data collection and data availability. Consequently, detailed OD road freight surveys have been undertaken very infrequently in Australia. The last 'comprehensive' survey of OD road freight movements was the Australian Bureau of Statistics' 2000–01 Freight Movements Survey (FMS) (ABS 2002).[2] However, even the scope of that survey was constrained—to articulated truck freight movements only—due in part to survey cost.

The Australian Government's increased focus on ensuring adequate planning and appropriate investment in infrastructure to support future growth and meet community needs, has increased the importance of accurate, detailed freight movements data to help inform infrastructure investment. Detailed freight movements data is also required to help evaluate the impact of alternative policy and regulatory arrangements. For example, the Council of Australian Governments (COAG) Road Reform Plan is undertaking research to investigate the merits of more direct heavy vehicle charging arrangements, and detailed network road freight data would help evaluate the impacts of alternative charging options.

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1 The author is grateful to two anonymous referees for their comments. All errors remain the responsibility of the author.

2 The Australian Bureau of Statistics (ABS) is currently investigating survey design issues and developing a business case for a new freight movements survey.

Administrative data sources, where available, may provide a cheaper alternative to sample survey approaches, since the data is already collected for business management purposes. Weigh-in-motion (WIM) site data is one such administrative data source that could potentially provide additional information about network road freight movements on monitored links. WIM sites capture information about heavy vehicle type (axle configuration), vehicle speed and (gross) vehicle mass, from which indicators of road freight activity at each site can be derived. Data from several WIM sites across a single highway or corridor may be pooled to produce trend freight movement estimates for that highway/corridor, complementing survey-based road freight movement data.

The Bureau of Infrastructure, Transport and Regional Economics (BITRE) is undertaking work to develop trend estimates of heavy vehicle traffic across non-urban corridors using annual time series WIM site data provided by state and territory road agencies. The data set covers the period 1995 to 2007, during which B-doubles have become the predominant road freight vehicle. This paper presents some preliminary results from BITRE's research. The preliminary results show the strong growth in road freight movements on Australian intercapital corridors over the last 15 years and the growth in B-double use for non-urban freight.

1.1 Paper structure

The remainder of the paper is structured as follows. Section 2 provides a brief overview of WIM technology, data items collected, vehicle classification, data accuracy and network coverage in Australia. Section 3 briefly describes the methodology used to derive trend freight task estimates from WIM site data and presents some preliminary non-urban freight trends for specific intercapital corridors. In Section 4 we briefly outline the limitations of the corridor-based approach and discuss the potential application of traffic matrix estimation techniques to the non-urban WIM site data. Section 5 provides some concluding remarks.

2. WIM technology – a brief overview

WIM technology is a combination of vehicle sensor(s) and mass measurement device that can classify vehicles, based on number of axles and axle spacing, and measure the dynamic load of each axle, in order to estimate the corresponding vehicle's static mass (Austroads 2000).

In Australia, the most common form of WIM system in use is the 'Culway' high-speed WIM system developed by Main Roads Western Australia in partnership with ARRB Transport Research. Culway WIM devices are a combination piezoelectric vehicle sensor and bending plate vehicle weighing technology. Culway WIM technology classifies and weighs vehicles using mechanical strain amplifiers deployed in under-road box culvert structures—hence the term 'Culway'.

Culway WIM systems employ two piezoelectric vehicle sensors placed approximately 10 metres apart to measure speed, axle configuration and axle spacing. The strain gauge equipment is synchronised with the vehicle detectors to measure the weight of each axle (MRWA 2003).

2.1 Information collected by Culway WIM data

For each vehicle, Culway WIM technology reports:

- date
- time
- vehicle speed
- gross vehicle mass (GVM)
- vehicle type (defined by axle count)
- Austroads vehicle class

- number of axles
- axle spacing
- axle group mass
- equivalent standard axles (ESAs)
- vehicle loading indicator – unladen, partially laden or overloaded.[3]

2.2 Vehicle classes

Culway WIM technology classifies vehicles according to number of axles and axle spacing and allocates vehicles into one of ten Austroads heavy vehicle classes. The WIM technology counts all vehicles passing the site but only records individual vehicle speed, axle configuration and axle mass data for heavy vehicles—Austroads vehicle classes 3 to 12. Six-axle articulated trucks, B-doubles and road trains (Austroads vehicle classes 9 to 12) generally account for over 90% of total road freight on most non-urban highway sections. On highway sections closer to urban areas rigid trucks are more prevalent and carry a higher share of freight, but articulated trucks still account for the majority of road freight moving past those sites.

2.3 Australian WIM sites

State and territory road authorities operate a relatively extensive set of Culway WIM sites across the non-urban highway network. There are also a few sites on strategic links in the major capital cities. There are WIM sites on all of the National Land Transport Network (NLTN) corridors.[4] Most intercapital corridors have at least two, and often more, WIM sites along the corridor. Figure 1 shows all WIM sites that have been operational for either all or part of the period between 1995 and 2009.

2.4 Vehicle acceptance parameters

The Culway analysis software is programmed with filters to validate vehicle information extracted from the raw data. A vehicle is excluded from the analysis if vehicle speed, axle spacing, axle weight and vehicle weights fall outside the vehicle acceptance parameter settings. Table 1 shows typical acceptance parameter settings used for Culway WIM data analysis.

Table 1: Typical Culway acceptance parameters

Parameter	*Culway setting*
Maximum vehicle speed	180 km/h
Minimum vehicle speed	20 km/h
Minimum axle spacing	0.5 metres
Maximum axle spacing	9.5 metres
Maximum axle weight	20 tonnes
Minimum vehicle weight	0 tonnes / 3 tonnes[a]

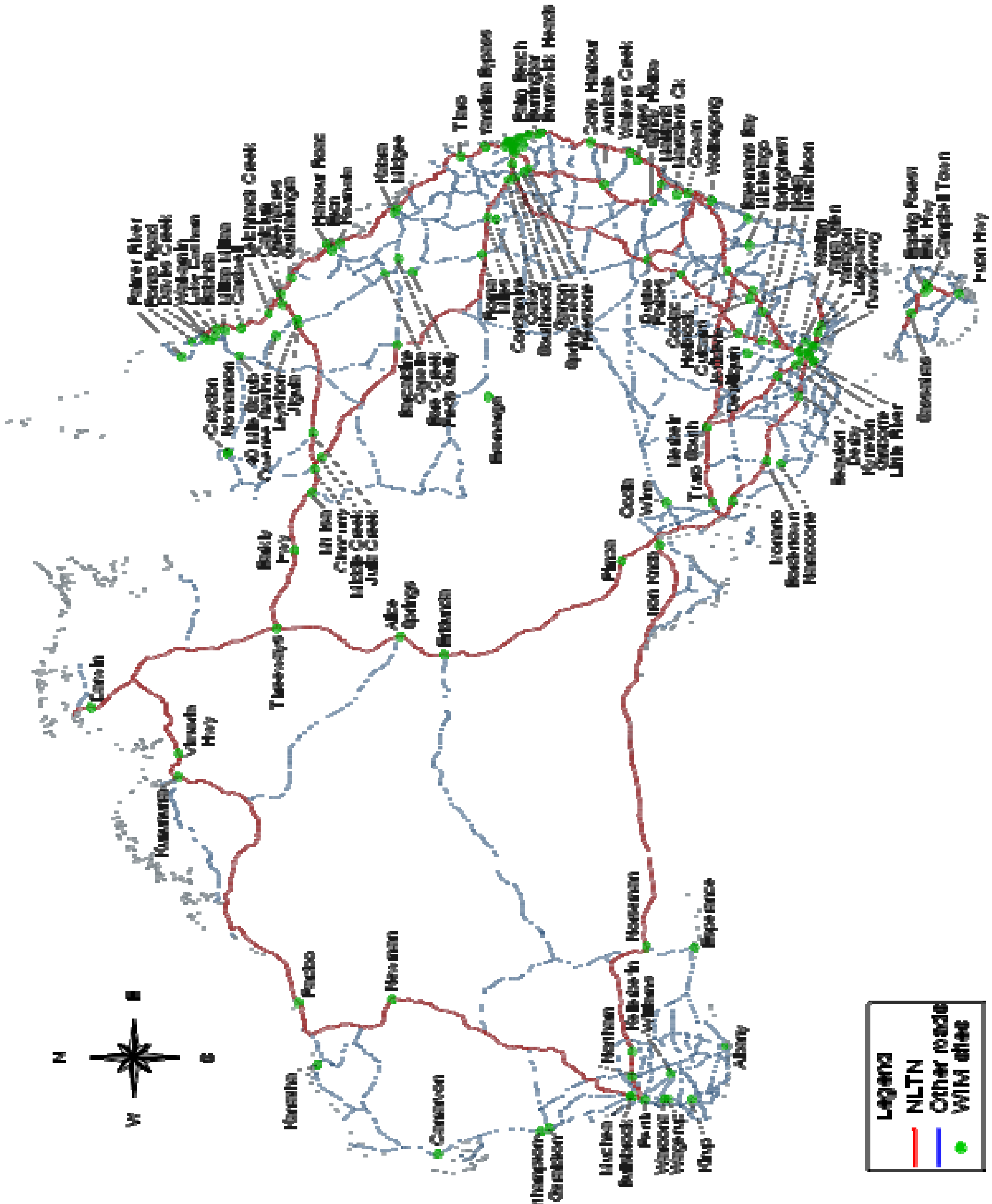
a. Northern Territory – 0 tonnes and South Australia – 3 tonnes.

Sources: Northern Territory Department of Infrastructure, Planning and Environment (2003) and Transport SA (2003).

3 The vehicle loading indicator is based on number of axles and axle group mass.

4 The NLTN broadly includes all roads connecting capital cities and also designated roads connecting capital cities and major centres of commercial activity.

Figure 1: Geographic coverage of Australian WIM sites



2.5 WIM data issues

According to Austroads (2000), the basic principles of WIM technology have been known for over 50 years. However, it took many decades to develop adequate instrumentation, mass sensors, computer processing and data storage in order to develop accurate WIM sensors. We briefly outline here some of the issues that affect WIM site data accuracy. The discussion draws heavily on Austroads (2000).

2.5.1 Accuracy and calibration

There are numerous factors that affect the ability of WIM systems to reliably and accurately determine (static) vehicle mass. Austroads (2000) identifies three key elements that affect the accuracy of WIM equipment:

- WIM location characteristics—principally the topology and topography of the WIM installation site and its approach
- vehicle characteristics—speed, acceleration/deceleration, body and suspension type, tyre condition and aerodynamic affects can all affect the performance of WIM equipment
- environmental characteristics—temperature, wind and ice can all significantly affect the performance of WIM equipment.

Accurate mass measurement using WIM equipment requires that the mass sensor(s) be properly calibrated and, to ensure that mass measurement accuracy does not deteriorate significantly, the devices should be re-calibrated at regular intervals (Austroads 2000). Calibration drift will affect the accuracy of vehicle mass measurement over time and is of particular concern in producing trend indicators. Of the WIM sites analysed to date, only the WIM site on the South East Highway (near Monarto, SA) exhibits extended calibration drift. (This is discussed further in Section 3.) Across other WIM sites there are generally only one-off (single year) anomalies in mass measurement.

Published indicators of in-situ Culway WIM device accuracy and reliability are limited. Austroads (2000) identifies three main types of WIM system errors:

- actual error—that is, an error in determining the true mass of the vehicle
- systematic error—e.g. flawed calibration or drift in calibration
- random error—that is, WIM system errors or vehicle characteristics.

Austroads (2000) also notes that there is no Australian standard method of determining and presenting WIM site accuracy results. Generally, the accuracy is specified in terms of the 95% tolerance of vehicles being weighed. Northern Territory Department of Infrastructure, Planning and Environment (2003), for example, states that the variation between static axle mass and Culway recorded values for axle group and gross vehicle mass is typically within ±10% for 95% of observations. For the purposes of trend analysis described in this paper, absolute accuracy is generally less important than temporal (calibration) consistency.

2.5.2 Lane discipline, vehicle speeds and site selection

Site selection is critical to the accuracy of information collected by Culway WIM equipment. MRWA (2003) recommends using the following criteria when assessing the suitability of Culway sites:

- straight alignment—a minimum of 120 metres each side of the Culway
- longitudinal grade preferably less than 1% but not greater than 2%
- cross-fall between 2% and 3%
- limited overtaking opportunity
- open speed section
- a section of fill providing adequate cover for the culvert after ensuring a culvert of minimum height 600mm can be placed above natural surface.
- culvert to be dry—that is, one not intended for drainage purposes.

MRWA (2003) also recommends that, while the Culway site should be located on a straight and level road section, the sight distance should not be so good as to make it an attractive overtaking opportunity for motorists. Poor lane discipline—due to overtaking manoeuvres or vehicles travelling out-of-lane—may result in reduced vehicle detection rates and reduced weighing accuracy.

Likewise, placing Culway sites too close to horizontal curves in remote areas may also result in invalid vehicle detection and inaccurate weighing as a result of poor lane discipline.

The speed of the traffic can also impact Culway results—normal highway speeds are desirable for optimal operation. Slow speeds, particularly speeds less than 30 kilometres per hour may reduce vehicle classification accuracy due to changes in vehicle acceleration. In addition, vehicles will probably be over-weighed. The presence of nearby intersecting roads or any other road geometry that causes traffic acceleration or deceleration over the Culway is highly undesirable (MRWA 2003).

2.6 Other WIM site data issues

Lane coverage of Culway WIM installations varies by site. At many sites, only a subset of lanes are monitored by Culway WIM equipment—heavy vehicles predominantly use the outer or kerb-side lane and for heavy vehicle traffic monitoring purposes it may be sufficient to monitor only the kerb-side lane at particular sites. Also, temporary outages to the Culway WIM equipment result in incomplete data capture.

Consequently, inferring aggregate road freight task estimates from WIM data requires adjusting the measured data for: (i) non-recorded days; and (ii) non-metered lanes.

2.6.1 Accounting for non-metered/non-strain gauged lanes

At sites where Culway WIM equipment does not cover all road lanes, the estimates are adjusted to account for heavy vehicles in non-metered lane(s). Adjusting the estimates for non-metered lanes generally involves comparing classified vehicle count data, collected by apparatus other than Culway WIM equipment, and scaling the Culway WIM estimates by the count data. At a few WIM sites, heavy vehicles are counted across all lanes, and these counts are used to scale the Culway WIM mass estimates.

Adjusting for non-metered and/or non-strain gauged lanes requires assumptions about the average mass of vehicles travelling in non-metered and/or non-strain gauged lanes. In the absence of data, average vehicle masses for non-metered lanes are assumed equal to the average mass in the mass-metered lanes at each site.[5]

2.6.2 Accounting for non-recorded days

Where the Culway WIM equipment does not record heavy vehicle movements for every day of the survey period, it is necessary to adjust the estimate to account for non-recorded days. Most jurisdictions provide both the number of recorded days and the number of vehicles counted on recorded days. In the analysis, all vehicle counts are first transformed to vehicles per day, for recorded days, and then annualised.

[5] This assumption may produce some slight bias in the freight task estimates. However, as most non-metered and non-strain gauged lanes generally carry only a small proportion of total heavy vehicle traffic any induced bias will tend to be small.

3. Non-urban road freight trends

3.1 Typical site data

Aggregated WIM site data typically includes classified vehicle counts, average speeds, average gross vehicle mass and average freight measured by the site equipment. Figures 2 and 3 illustrate some of the data accuracy and calibration issues raised in Section 2.

Figure 2 shows northbound recorded vehicles per day and average loads for five combined heavy vehicle classes at the Armidale WIM site (New England Highway, NSW) between 1995 and 2009. Daily heavy vehicle movements exhibit considerable variation at this site. The 1997 raw northbound heavy vehicle traffic data at this site contains a disproportionately large ratio of rejected vehicles to vehicles weighed, resulting in a disproportionately small number of recorded heavy vehicle movements. And the number of vehicles per day in 2002 also appears to be well below trend, across all vehicle classes. Except for the year 2000, recorded average vehicle loads are relatively stable across the observation period. The implied raw freight task estimates are shown in Figure 2. The estimates reflect the below average number of vehicles per day reported in 1997 and 2002 and the below average vehicle loads reported in the year 2000.

Figure 3 shows an example of a WIM site where calibration drift has occurred over the observation period. The number of heavy vehicles per day is relatively stable, but average loads exhibit noticeable calibration drift—underreporting of average vehicles loads across all heavy vehicle categories—between 2000 and 2003. Transport SA (2003) notes that this site experiences extreme fluctuation in temperature sensitivity, with changes in the temperature and moisture of the pavement appearing to dramatically affect the ‘stiffness’ of the deep asphalt pavement. Calibration factors have to be constantly adjusted to compensate for these environmentally-induced fluctuations. Repair and re-calibration of the WIM site in 2004 is readily apparent in the data. Figure 3 also shows the impact of calibration drift between 2000 and 2003 on the raw freight task estimates.

3.2 Estimating non-urban road freight trends

To estimate trends in non-urban road freight, we used a series of three mixed effects models estimated separately for each intercapital corridor:

- Step 1: Estimate a mixed effects model of average annual daily heavy vehicle traffic volumes, regressed against a time trend term, across all WIM sites along the corridor
- Step 2: Estimate a mixed effects model of heavy vehicle traffic shares, regressed against a spline time trend term, across all WIM sites on each corridor
- Step 3: Estimate a mixed effects model of average heavy vehicle loads, by heavy vehicle type, regressed against a spline time trend term, across all WIM sites on each corridor.

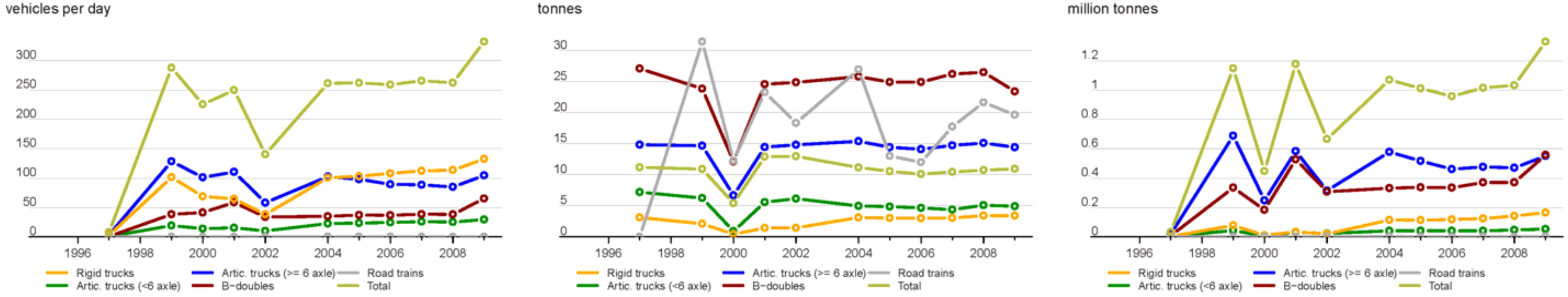
The mixed effects model specification has the following functional form:

$$y_{ijt} = \alpha_i + \beta s(t) + b_{ij}\, s(t) + \varepsilon_{it} \qquad \text{where } b_{ij} \sim N\left(0, \sigma_b^2\right) \text{ and } \varepsilon_{it} \sim N\left(0, \sigma^2\right) \qquad (1)$$

Subscripts i, j and t denote WIM site, vehicle class and time, respectively. y_{ijt} is the dependent variable, $s(t)$ is the spline trend term function, α_i captures differences in intercepts across WIM sites, β captures the common trend impacts and b_{ij} captures the random trend effects across sites and vehicle classes. The vehicle class terms (denoted by the j subscripts) do not apply to Step 1.

Space does not permit inclusion of the estimation results for each intercapital corridor here. Instead we briefly illustrate the results for the Sydney–Melbourne corridor.

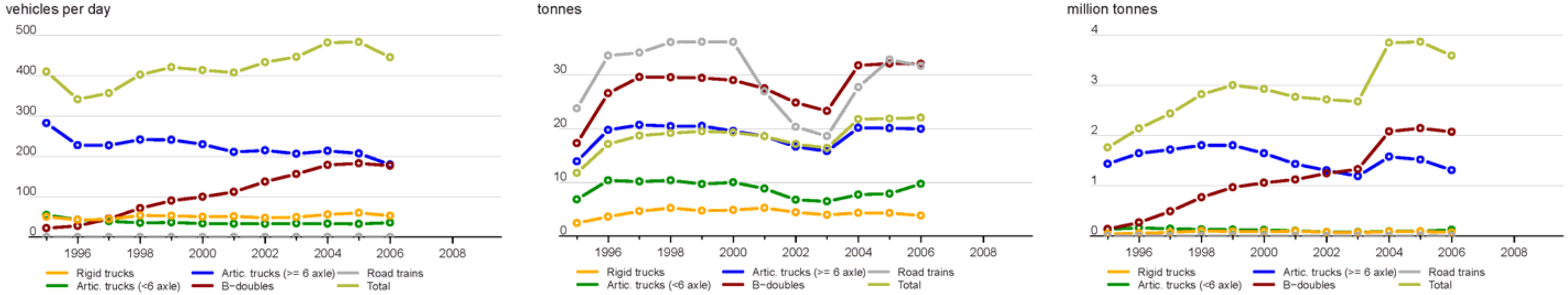
Figure 2: Armidale WIM site, New England Highway, northbound vehicles per day, average heavy vehicle loads and estimated freight



(a) Vehicles per day (b) Average load (c) Total annual freight

Source: WIM data supplied by New South Wales Roads and Traffic Authority (RTA).

Figure 3: Bordertown WIM site, Dukes Highway, westbound vehicles per day, average heavy vehicle loads and estimated freight



(a) Vehicles per day (b) Average load (c) Total annual freight

Source: WIM data supplied by Transport SA.

Figure 4 shows actual average annual daily heavy vehicle traffic volumes at the three separate WIM sites on the Sydney–Melbourne corridor—Holbrook (Site ID: HO), Springhurst (HSG) and Wallan (WAN, WAL)—and the mixed effects model predicted values. Separate estimates are provided for each direction (N–northbound, S–southbound). The specification includes fixed effects for the intercepts and random effects for the time trend term, which allows for variations in trend growth across different sites along the corridor. It can be observed from Figure 4 that the mixed effects trend specification predicts growth in average annual daily heavy vehicle traffic reasonably well. Outlying observations are immediately apparent.

Figure 5 shows the actual and mixed effects model predicted heavy vehicle traffic shares across the three WIM sites on the Sydney–Melbourne corridor. The inclusion of the spline trend term captures well the trend growth in B-double vehicle movements. Inclusion of a period specific dummy variable was also necessary to adequately account for the increase in rigid truck numbers on the Victorian sections of the Hume Highway observed since 2005. Road trains are a small proportion of total heavy vehicle movements on the Hume Highway.

Figure 4: Actual and predicted average annual daily heavy vehicle traffic, Sydney–Melbourne corridor WIM sites

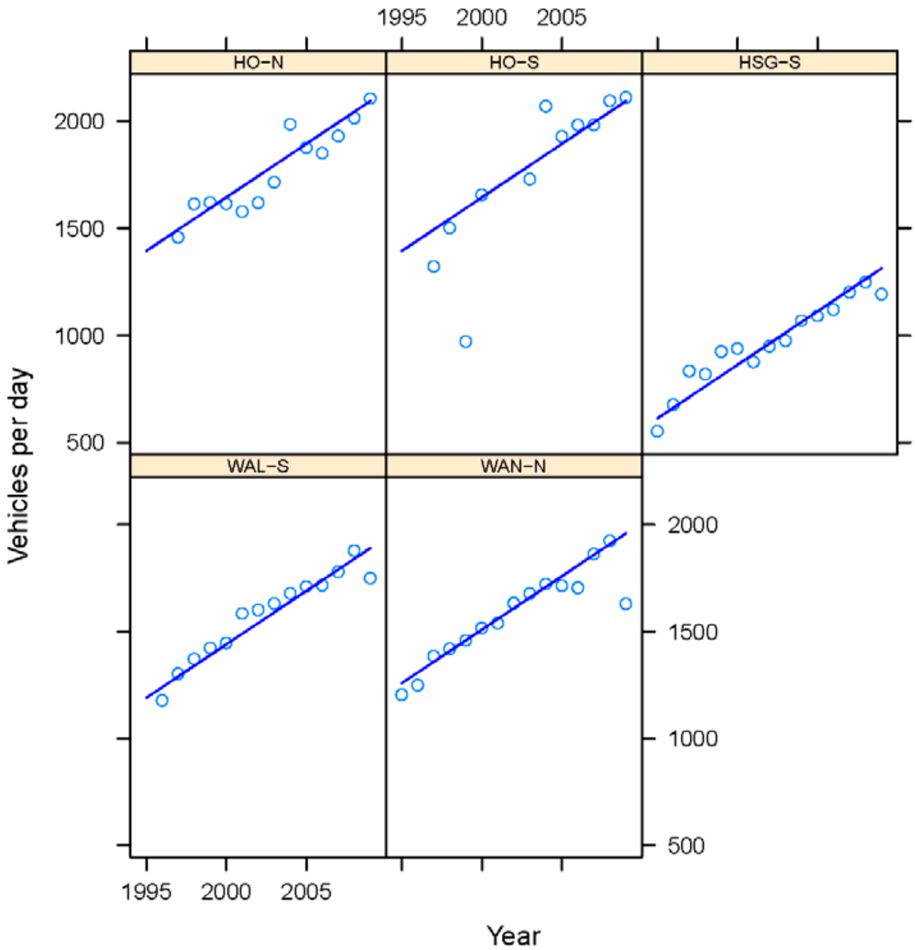
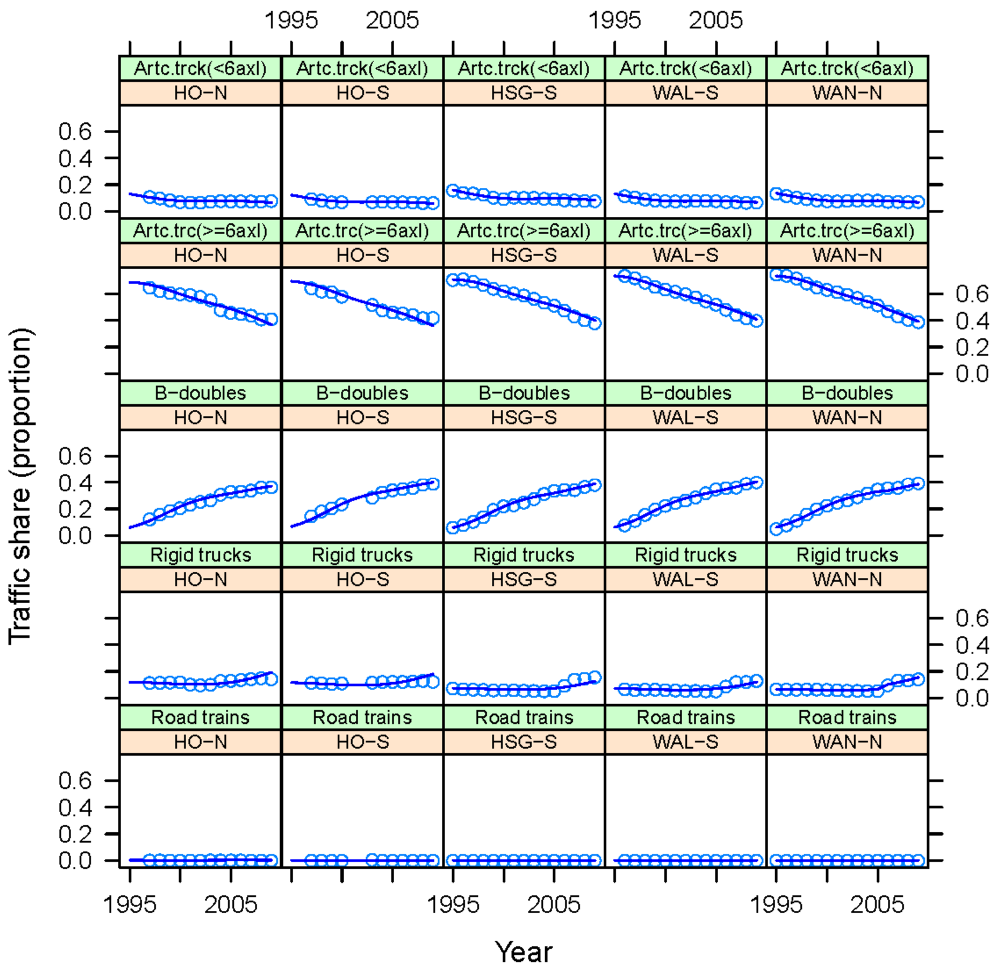


Figure 6 shows the actual and mixed effects model predicted heavy vehicle average vehicle loads across the three WIM sites on the Sydney–Melbourne corridor. Dummy variables were included to account for recorded variations in average loads at Holbrook—site IDs: HO-N and HO-S) between 1999 and 2003 and at Victorian WIM sites since 2006. Apart from these issues, it is clear that average heavy vehicle loads are reasonably similar across the different sites on this corridor. The estimation results also imply that average vehicle loads have not changed significantly over the observation period, although there is some evidence of a slight increase in average loads post-2005 across the Victorian sites on this corridor.

Figure 5: Actual and predicted average heavy vehicle traffic shares, Sydney–Melbourne corridor WIM sites



3.3 Deriving corridor-specific road freight trends

The trend estimates of total heavy vehicle traffic volumes are multiplied by class-specific heavy vehicle traffic shares to derive class-specific heavy vehicle traffic volumes. Class-specific heavy vehicle traffic volumes are multiplied by class-specific average loads and summed to provide estimates of total freight volume trends across the corridor. Figure 7 shows the WIM-based heavy vehicle freight trends for the Sydney–Melbourne corridor.

Some of the features of the WIM site-based road freight trends for the Sydney–Melbourne corridor are:

- Total heavy vehicle traffic volumes increased by approximately 60% between 1995 and 2009 (equivalent to average annual growth of 3.1% per annum). Southbound heavy vehicle traffic volumes grew slightly faster than northbound traffic. B-double vehicle numbers increased more than 10 fold over that period, from around 6% of all heavy vehicles in 1995 to approximately 40% of all heavy vehicles in 2009—increasingly supplanting six-axle articulated trucks.
- Heavy vehicle average loads exhibit only muted growth across each vehicle group. Averaged across all heavy vehicles average loads increased by one-third between

1995 and 2009 (equivalent to average annual growth of 2.1% per annum), heavily influenced by increasing B-double volumes. Average loads grew slightly more strongly for southbound traffic.

- Total freight volumes more than doubled between 1995 and 2009 (equivalent to average annual growth of 5.6% per annum). Southbound freight volumes grew by 6.1% per annum, northbound freight volumes by 5.1% per annum.
- Total B-double freight volumes increased nearly eleven-fold between 1995 and 2009, from around 11% of total freight in 1995 to nearly 60% of total freight in 2009, largely displacing six-axle articulated trucks as the preeminent road freight vehicle—the share of freight carried by six-axle articulated trucks has fallen from near 80% in 1995 to less than 40% in 2009.

Figure 6: Actual and predicted average heavy vehicle loads, Sydney–Melbourne corridor WIM sites

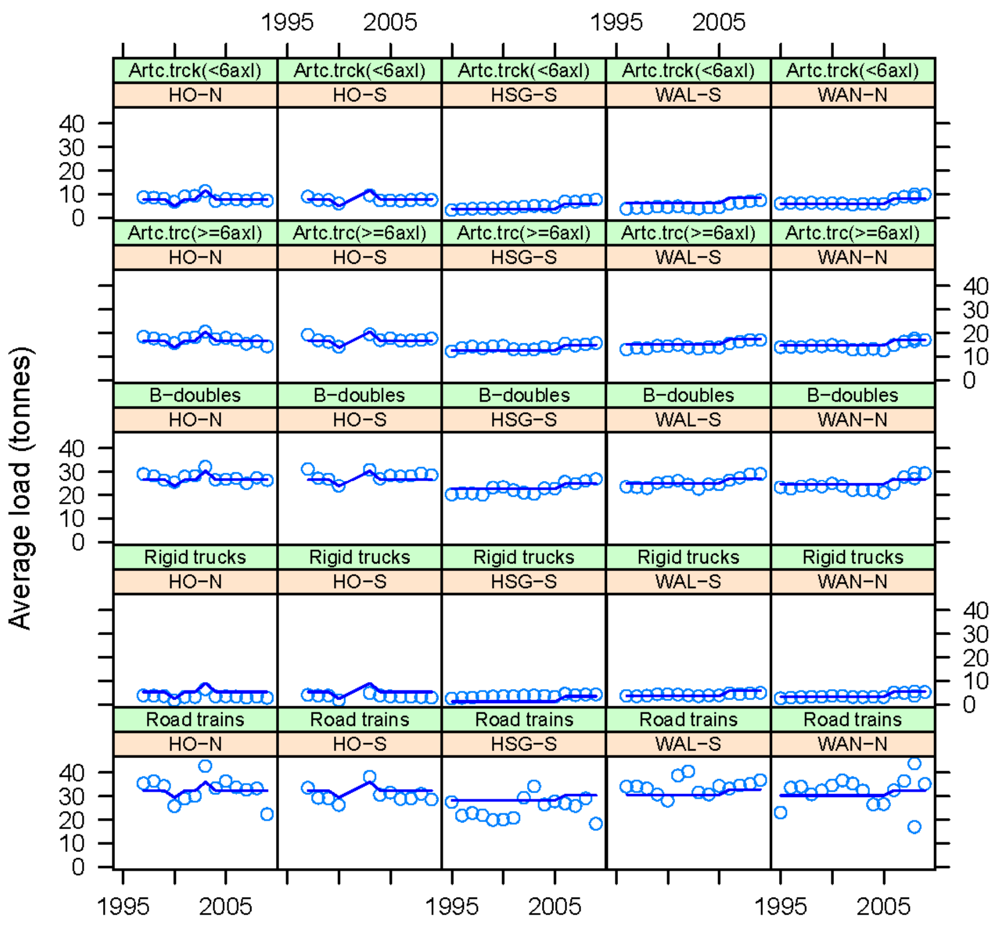
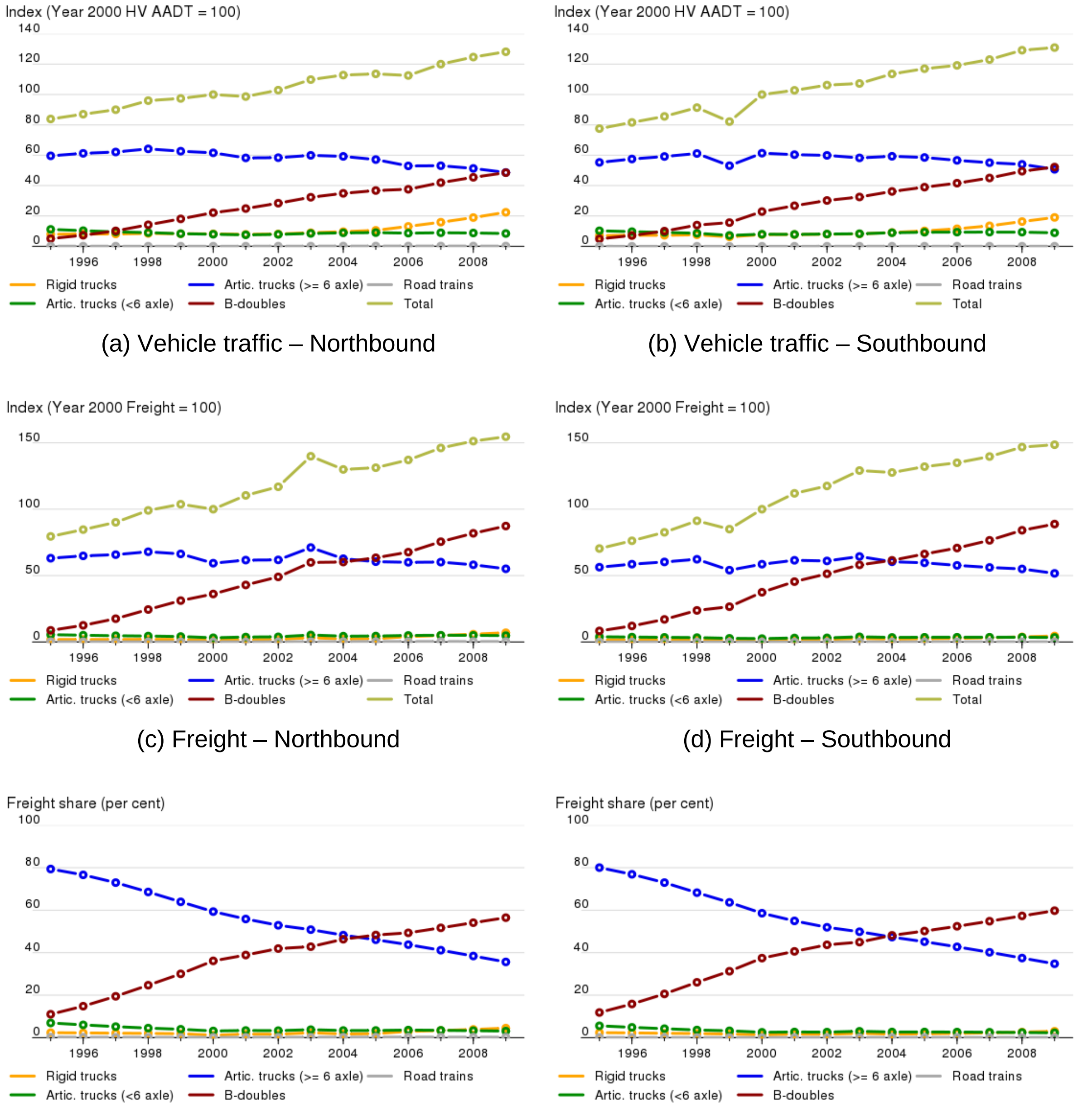


Figure 7: Sydney–Melbourne WIM-based heavy vehicle trends



(a) Vehicle traffic – Northbound

(b) Vehicle traffic – Southbound

(c) Freight – Northbound

(d) Freight – Southbound

(e) Freight share – Northbound

(f) Freight share – Southbound

Sources: New South Wales Roads and Traffic Authority (RTA), VicRoads and author's estimates.

3.4 Non-urban road freight trends on other corridors

At the time of writing, BITRE had completed trend analysis only for the major east cost intercapital corridors:

- Sydney–Melbourne
- Sydney–Brisbane (via Pacific Hwy)
- Sydney–Brisbane (via New England Hwy)
- Sydney–Adelaide
- Melbourne–Brisbane
- Melbourne–Adelaide

Analysis of trends for other corridors, including Brisbane–Cairns, Brisbane–Darwin, Adelaide–Perth, Adelaide–Darwin and Perth–Darwin is yet to be completed.

The corridors for which analysis had been completed generally exhibit similar results to those of the Sydney–Melbourne corridor—that is, strong growth in total road freight since 1995, little increase in class specific average vehicle loads and significant growth in movement of freight by B-doubles, largely displacing six-axle articulated trucks. Table 2 shows the WIM-based trend average annual growth in total freight for the major corridors analysed to date.

The major exception is the Sydney–Brisbane corridor. On that corridor, the granting of access to B-doubles to the entire length of the Pacific Highway in August 2002, following upgrade of the Yelgun–Chinderah highway section, resulted in a significant shift of heavy vehicle traffic from the New England Highway to the Pacific Highway. This shows up in the WIM-based trend estimates (see Figure 8), note the rapid growth in freight on the Pacific Highway after 2002, driven principally by the growth in B-double freight traffic, and the more muted growth in freight traffic on the New England Highway and absolute drop in B-double vehicle numbers on the New England Highway in 2003.

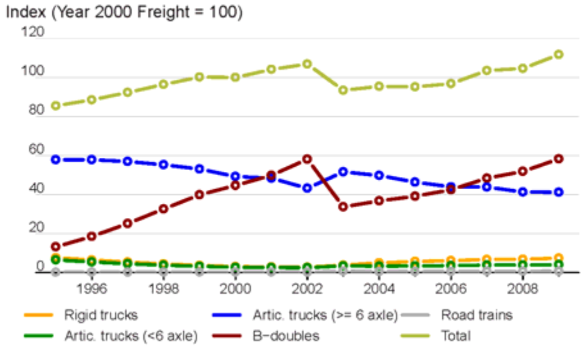
Table 2: Average annual growth in WIM-based freight task estimates for selected intercapital corridors

(per cent per annum)

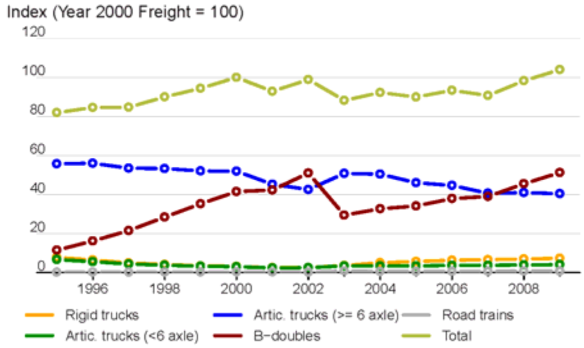
		Single-trailer articulated trucks				
Direction	*Rigid trucks*	*< 6 axles*	*≥ 6 axles*	*B-doubles*	*Road trains*	*Total*
Sydney–Melbourne						
Northbound	10.26	–0.38	0.08	19.07	4.80	5.96
Southbound	7.67	–1.37	–1.02	17.96	3.87	5.10
Total	8.92	–0.87	–0.53	18.44	4.44	5.48
Sydney–Brisbane (via Pacific Highway)						
Northbound	9.03	6.39	5.98	49.69	16.52	10.23
Southbound	10.50	7.51	6.96	51.32	17.52	11.39
Total	9.76	6.94	6.47	50.50	17.02	10.80
Sydney–Brisbane (via New England Highway)						
Northbound	–0.19	–3.25	–2.40	11.17	9.22	1.93
Southbound	–0.39	–3.40	–2.27	11.25	9.32	1.71
Total	–0.29	–3.32	–2.34	11.21	9.27	1.83
Melbourne–Brisbane						
Northbound	9.39	4.54	4.61	29.21	25.44	13.70
Southbound	8.69	3.73	4.12	28.99	25.27	13.16
Total	9.03	4.13	4.35	29.09	25.35	13.42
Sydney–Adelaide						
Eastbound	3.96	–0.61	–1.38	26.72	1.39	7.99
Westbound	2.96	–1.18	–1.78	26.16	0.37	7.37
Total	3.50	–0.89	–1.59	26.44	0.85	7.68
Melbourne–Adelaide						
Eastbound	7.64	3.31	0.56	21.91	1.20	6.88
Westbound	7.36	3.28	0.47	21.64	0.74	6.74
Total	7.50	3.29	0.52	21.76	0.92	6.81

Sources: New South Wales Roads and Traffic Authority (RTA), VicRoads and author's estimates.

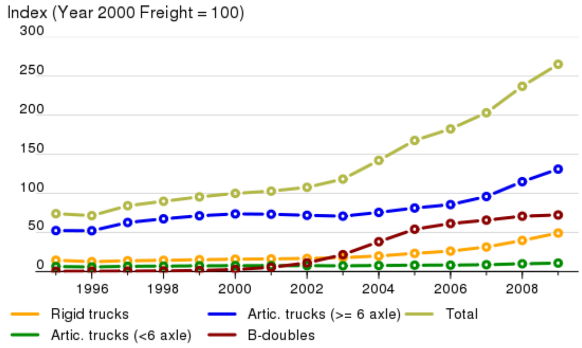
Figure 8: Sydney–Brisbane WIM-based freight trends



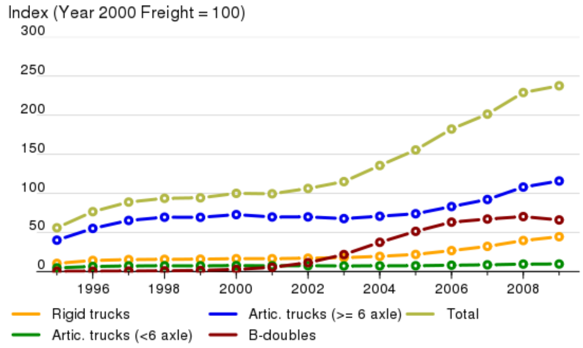
(a) Via New England Highway – Northbound



(b) Via New England Highway – Southbound



(c) Via Pacific Highway – Northbound



(d) Via Pacific Highway – Southbound

Sources: New South Wales Roads and Traffic Authority (RTA), Queensland Department of Transport and Main Roads (QTMR) and author's estimates.

4. Traffic matrix estimation and non-urban WIM site data

The benefits of pooling data from across several WIM sites on the one corridor are that it provides a means of deriving freight trends, extrapolating across missing observations and reducing the influence of outlying observations on the trend estimates.

The approach yields valuable insights into freight movements across different corridors, such as the observed shift in freight from the New England to the Pacific Highway, and is fine for corridors where trend growth in vehicle traffic and freight volumes is similar across the length of the corridor. However, the approach is less satisfactory for corridors where trends will vary across the corridor. An example of the latter is the Brisbane–Darwin corridor, where road freight volumes are larger and freight growth quite high between Brisbane–Toowoomba–Miles, but volumes are much lower and growth far less across the rest of the corridor (Miles–Darwin). Across that corridor, satisfactory trend analysis is likely to require separately estimating freight trends for different sections of the corridor. Hence, there is an element of arbitrariness to the corridor-based approach and it would be far preferable to use all the WIM data in a consolidated framework, rather than using the arbitrary corridor-based definitions.

Traffic matrix estimation techniques have been used by many authors to derive trip matrices from traffic count data. These methods combine some base period, or 'prior', OD matrix with up-to-date traffic flow information to derive updated OD matrices. Ortuzar and Willumsen (2001) provide an introduction to early traffic matrix estimation techniques. Kolaczyk (2009) provides an overview of recent developments in traffic estimation techniques, including Bayesian (e.g. Tebaldi & West 1998) and entropy minimising (e.g. Zhang, Roughan, Lund and Donoho 2003) traffic matrix estimation methods. In the current context, it may be feasible to use the WIM site freight task estimates to derive updated OD matrices for longdistance Australian road freight. As part of BITRE's project, it intends to assess the feasibility of using the available WIM site data to derive updated OD road freight matrices.

An extension of traffic matrix estimation techniques is to use the information to determine the optimal number and location of link counts necessary to estimate the OD traffic matrix to within a specified error range. It may be the case that installation of a few additional, strategically-placed WIM sites would enable derivation of annual OD road freight matrices, with a comprehensive OD road freight survey required infrequently, for example, once every five to ten years.

5. Concluding Remarks

This paper has presented some preliminary results from BITRE's project to derive non-urban freight trends from WIM site data. The trends imply that non-urban road freight on the major intercity highways has grown quite strongly since 1995—by over 5% per annum on the Sydney–Melbourne corridor and by up to 13.5% per annum on the Melbourne–Brisbane corridor. This is above the average rate of growth in total road freight over this period, which has been around 4% per annum. The data also reveals the impact of growth in B-double use on intercapital corridors.

The WIM data complements other data sets, and provides more up-to-date information on trends in non-urban road freight. The non-urban freight trend information will assist in the development and update of NLTN corridor strategies, provide more accurate base year freight traffic volumes that will better inform infrastructure investment evaluation. The existing WIM site data could potentially be used to produce up-to-date OD freight matrices enabling derivation of more up-to-date network wide road freight flow information.

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