

# Evaluating the impact of bus network planning changes in Sydney, Australia

Corinne Mulley<sup>1,2</sup> and Chinh Ho<sup>1</sup>

<sup>1</sup>Institute of Transport and Logistics Studies, The University of Sydney, NSW 2006 Australia

<sup>2</sup>Email for correspondence: [corinne.mulley@sydney.edu.au](mailto:corinne.mulley@sydney.edu.au)

## Abstract

The paper analyses the impact of the bus reform package implemented in Sydney, Australia from 2005 onwards, focusing on the impact of bus network planning changes. The network planning changes included the concentration of services into corridors, more direct services, and greater network connectivity. Bus supply data and patronage data is analysed for the 15 metropolitan bus contract regions in Sydney to test whether network planning changes increased patronage and whether the trade-offs in service planning had greater benefits than losses. Results show that changes in bus boardings are mainly driven by changes in km supplied, and that there are significant differences between the contract regions operated by State Transit Authority and private operators. The network reviews have a significant impact on boardings in several contract regions over and above the additional km supplied. The paper provides input into the policy evaluation surrounding the impact of network planning on supply and demand in the metropolitan area of Sydney.

## 1. Introduction

From 2005 onwards, the New South Wales government embarked on a major program of bus reform by accepting most of the recommendations of a review which it had commissioned to improve the viability of the bus industry (Unsworth, 2004). The initial focus of bus reform to stabilise the bus industry has been extended to increase public transport use, consistent with other government policy. The package of bus reform included changes to planning of bus services, contracting and funding. This research focuses on the impact of the network planning changes undertaken as part of the bus reform and other major impacts on bus supply.

Based on the service planning guidelines for metropolitan bus regions (NSW, 2006 Ministry of Transport), new bus networks in each of the 15 metropolitan bus contract regions in Sydney were progressively implemented which focused on strategic bus corridors, simplification of services, and integration of services with adjoining bus contract regions. The principles of network planning suggest these changes should increase patronage. However budget constraints mean trade-offs are made, particularly between frequency and coverage. The research examines whether the network changes increased bus patronage, recognising a number of related changes such as physical and electronic bus priority, fare reform and interchange improvements to increase bus use. Analysis is based on the 15 metropolitan bus contract regions in Sydney, which have had various combinations of network planning and other changes.

The evaluation of the impact of bus reform will help inform the development of the next round of bus service contracts which were due for renewal from December 2011 onwards. A press release on 1 May 2012 (TfNSW, 2012) has indicated that the next round of bus contracts are going to be subject to competitive tender, starting with the publication of tender details in July 2012 for four contract regions. Moreover, although Service Planning Guidelines were being reviewed (2011) by the NSW Government it is not clear how planning responsibilities will be divided between the NSW Government and the successful operator, following competitive tender.

The paper is structured as follows: section 2 provides background on network planning principles and the bus planning environment in Sydney. Section 3 looks at supply and demand at an aggregate level whilst section 4 presents an evaluation on a contract region by contract region basis. Section 5 models demand and supply and discusses the implications of this model, and section 6 makes conclusions.

## 2. Background

### 2.1 Network planning principles and increasing patronage

The principles of bus network planning include simplicity, legibility, frequency and spatial coverage, although they may be phrased differently (Nielsen et al., 2005). These principles guide planning in many jurisdictions. For instance, Mees and Dodson (2011) reviewed public transport planning principles in Australian cities (although the Service Planning Guidelines which guide bus service planning in Sydney are not referenced) and Mees et al. (2010) reviewed public transport network planning principles in New Zealand.

Research indicates that focusing on these principles of network planning should increase patronage (Nielsen et al., 2005; Currie and Wallis, 2008; Parker, 2011), although quantitative evidence, particularly on the nature of trade-offs, is often unclear. Trade-offs are made between frequency and coverage, and between direct services and coverage in response to budget constraints. In addition, the response to network change depends on the previous level of service, and different characteristics of users.

The concentration of resources into corridors, simplifying routes to be direct routes and providing a 'forget the timetable' level of frequency all help to create and support the network effect in the provision of public transport and increase patronage. The network effect is where higher than expected patronage for a single route follows seamlessly interconnected routes into a network. However, the efficiency and simplicity of direct routes and concentration of frequency often brings with it a need for passengers to interchange to achieve their desired journey. Whilst all journeys where an interchange is necessary will result in the interchange being seen as a penalty, strategies to minimise this penalty is properly part of network design (Nielsen et al 2005).

In Melbourne, Parker (2011) evaluated the impact of bus planning changes and concluded 'service planning quality advanced slower than service quantity' with a reluctance to apply the network planning principles described above. Currie and Loader (2010) reviewed bus transfer behaviour, identifying half of bus users make transfers, mostly to rail. Currie and Loader conclude that high transfer volumes occur where at least one route has a frequency of 10 minutes or better, but conclusive proof of the network effect remains elusive.

In Sydney, travel time and frequency are concerns for public transport users. Daniels and Mulley (2011) showed that travel time for all trip purposes in Sydney is markedly longer for trips made by public transport than by car. This finding is supported by Emerson and Parolin (2011). A customer satisfaction survey of Sydney bus users showed that dissatisfaction was high for frequency of the bus service (23% of all bus users dissatisfied), third highest behind bus being on time and being informed of service changes (BTS, 2011).

The service planning guidelines in Sydney outline both the principles of planning services, and the process of change. The philosophy behind network changes is discussed in the next section.

### 2.2 Bus services in Sydney

In Australia, there is considerable interest in improving public transport accessibility which is being expressed at national and state Government levels and also at the community level. The NSW Government strategic planning documents including the *Metropolitan Plan* (NSW, 2010a), and *State Plan* (NSW, 2006; 2010b; 2011) have targets for improving public

transport use and accessibility, and related objectives such as reducing obesity which also rely on increased public transport use. In Sydney, more trips are undertaken by bus than by rail (TDC, 2010) and bus services are an important part of the public transport mix due to their flexibility, low costs and local role. The federal government also supports increased public transport in its urban policy documents (Australian Government, 2011). The Institute of Transport and Logistics Studies (ITLS) Transport Opinion Survey (TOPS) shows strong community support for public transport improvements ahead of road improvements in NSW (Daniels and Hensher, 2011).

**Table 1 Characteristics of metropolitan bus contract regions as at 2011**

CR	Contract Region	Operator	Area (km <sup>2</sup> )	Pop. ('000s)	Pop. Den. ('000/km <sup>2</sup> )
1	Blacktown - Penrith - Richmond - Windsor	Busways, Westbus and Hawkesbury Valley Bus and Coach Service	1,217	503	0.41
2	Liverpool – Glenfield – Ingleburn – Bringelly – Hoxton Park	Busabout and Interline Bus and Coach Service	377	157	0.42
3	Fairfield - Cabramatta - Liverpool - Wetherill Park	Westbus, Hopkinsons, Metrolink and Busabout	156	316	2.02
4	Blacktown – Rouse Hill - Castle Hill – Dural – Parramatta	Hillsbus	666	338	0.51
5	Lakemba – Mortdale – Punchbowl – Roselands	Punchbowl Bus Company	59	215	3.64
6	Inner West (Sydney Olympic Park – Burwood – Ashfield – Leichhardt – Campsie – Rockdale)	State Transit Authority	148	543	3.67
7	Inner North (North Sydney - Chatswood - Macquarie Park - Epping - Ryde - Parramatta)	State Transit Authority	129	347	2.69
8	Northern Beaches (Palm Beach - Brookvale - Manly - Mosman - North Sydney)	State Transit Authority	116	271	2.34
9	East (Bondi Junction – Randwick – Maroubra – Botany – Mascot – Surry Hills)	State Transit Authority	101	404	4.00
10	South (Hurstville - Miranda - Menai - Bankstown)	Connex	172	283	1.64
11	Caringbah – Cronulla – Kurnell – Miranda	Buslink	141	70	0.49
12	North (Berowra – Hornsby – Gordon – Chatswood)	Shorelink	234	184	0.79
13	Parramatta - Burwood - Bankstown - Liverpool	Transit First	133	278	2.08
14	Chatswood – Belrose – Terrey Hills – St Ives	Forest Coach Lines	203	74	0.36
15	South West (Campbelltown – Narellan – Camden)	Busways	612	149	0.24

Source: Bureau of Transport Statistics (Data request 12/104)

In Sydney, over the period covered by this research, bus services are provided by operators contracted to the NSW government. There are 15 metropolitan bus contract regions, with the government-owned operator State Transit Authority (STA) providing services in 4 regions, and private-owned operators providing services in the remaining 11 regions. All operators are paid a per km rate, and all fare revenue is retained by government. The current bus contracts are worth \$5.6 billion over seven years (NSW Audit Office, 2010). Under the bus reform process introduced in 2005, the number of bus contract regions was reduced from 87 to 15, and services are planned by the operators and government following the principles

and processes in the Service Planning Guidelines (NSW, 2006). The characteristics at the time of bus reform for the different contract areas for the metropolitan area of Sydney are presented in Table 1.

The Service Planning Guidelines outline the process for making network changes including a process of public consultation which involves annual planning forums and public brochures. These principles underpin the philosophy behind the network reviews which were progressively undertaken as part of the bus reform package. Different contract areas placed different emphasis on elements of network planning principles, as indicated by the descriptions in the public consultation brochures. For example, in the more established networks in Eastern Sydney (operated by State Transit Authority), the aim was to simplify comprehensive networks, whereas in contract regions with lower density or newer areas where previously there were multiple smaller networks as legacy from the previous contracts, the emphasis was on synthesising to provide a single network. The analysis of the nature and impact of network planning changes in Sydney, as presented in this paper, will contribute to a better understanding of how network planning can lead to public transport being provided more effectively to increase patronage.

### 2.3 Significant events for bus services in the metropolitan area of Sydney

A key element of this evaluation of bus reform is to identify the relationship between changes in bus km and patronage, whether this relationship varies by contract region and whether the introduction of networks embracing the strategic corridors and concentration of resources with simpler and more direct routes led to higher patronage.

**Table 2 Summary of the major events affecting demand and supply of bus services in Sydney between 2005 – 2012**

Date	Event
01/2005	Expansion of PET to private buses, New contract signed with first operator
10/2005	All contracts signed
03/2007	Opened Stage 1 of the North-West T-Way (Parramatta – Rouse Hill)
11/2007	Opened Stage 2 of the North-West T-Way (Blacktown – Parklea)
10/2008	Introduction of discounted weekly ticket on private bus services (discounted weekly tickets already existed on STA services), launch of Metrobuses
12/2008	Sydney CBD shuttle bus commenced, Funday Sunday ticket (giving heavily discounted family travel on Sundays)
06/2009	TravelTen concession extended
04/2010	MyZone fare reform introduced, extending multi-modal passes to private bus operators
03/2011	Metrobuses expanded, CBD shuttle buses introduced
05/2012	Announcement of the competitive tendering of bus contract region contracts

*Source: NSW Ministry of Transport (2005; 2006; 2007; 2008), Transport NSW (2010c) Department of Transport (2011).*

The analysis below covers a timeline from 2005 until 2011. Other events and policy changes will have impacted on the connections between supply and demand. A timeline of major changes which may affect interpretation of results within individual bus contract regions and across Sydney, such as the opening of the North West Transitway in March 2007, or the introduction of fares and ticketing changes such as the Pensioner Excursion Ticket extension to private buses in 2005, and MyZone fare reform in April 2010 was compiled from multiple sources. Apart from these major changes there will be other local changes such as the implementation of bus lanes and electronic bus priority measures to improve reliability and reduce travel time, and supportive infrastructure such as interchange upgrades. Table 2 summarises these major events.

The introduction of Metrobuses began in October 2008 with high frequency, high capacity services which were originally cross Sydney CBD services to link key employment services. These services were branded and the vehicles painted red. Since these services were first introduced, Metrobus services have been added to the network (usually over and above the existing network). Table 3 shows a timeline for the roll out of Metrobus services and the contract region in which their kms are counted.

**Table 3 The timeline for the introduction of Metrobus services in Sydney and the contract region of operation**

Metrobus	M10	M20	M30	M40	M52	M50	M54	M41	M61	M90	M91	M60	M92
Launched	Oct-08	Oct-09	Mar-10	Jul-10	Aug-10	Oct-10	Oct-10	Dec-10	Dec-10	Dec-10	Feb-11	Mar-11	Mar-11
Region	9	6	6	6	7	6	7	6	4	13	13	4	10

Source: Department of Transport (2011).

Before turning to examine the data in more detail, it should be noted that the changes outlined in this section are likely to have a different effect on different contract regions depending on the characteristics of the network, the characteristics of the operator (public or private) and the characteristics of the user population in terms of their socio-demographics. The way in which particular changes impact on different operators and the contract regions, where this can be more specific, is discussed in the results section below.

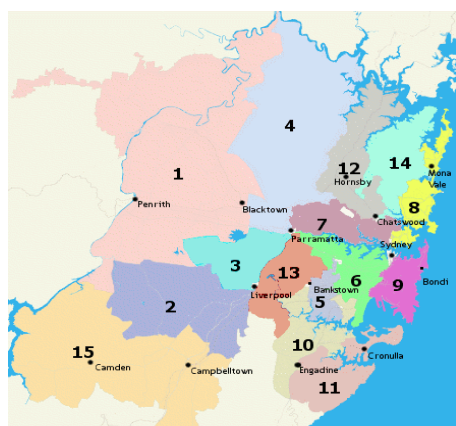
### 3. Aggregate Supply and Demand

#### 3.1 Supply of bus kms

Data on monthly bus kms for each of the 15 metropolitan bus contract regions during the 2005 – 2011 period was sourced from the Bureau of Transport Statistics (BTS) at Transport for NSW, based on self reported data from operators to the Transport for NSW as the regulator. The data used to represent supply is the kms operated by each route, aggregated to the contract region for each calendar month and excluding school services and dead running. In checking and cleaning the data, it is clear that this self-reported data by operators to the regulator contains some data quality issues, more particularly evident early in the series.

As shown by Figure 1, the contract regions are of different size and reflect different urban operating environments. Density is higher in the areas closer to the heart of Sydney with lower density environments in the fringe areas. Bus kms per financial year have been adjusted by population and are presented in Figure 2 as service km per capita for each contract region.

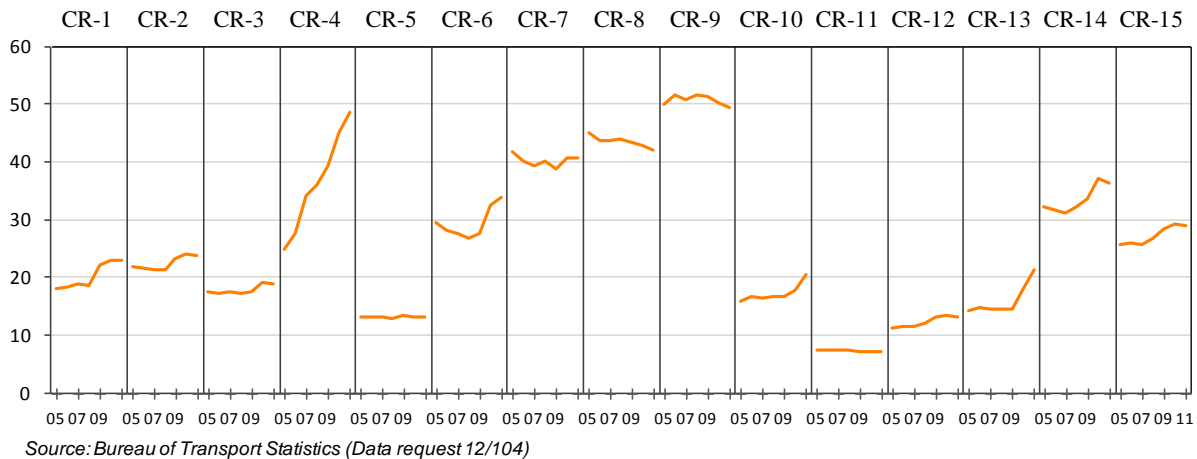
**Figure 1 Location of metropolitan bus contract regions in Sydney**



Source: <http://www.nswbusnetwork.com.au/index.html>

Figure 2 shows significant differences in the public transport offer between contract regions on a per capita basis. The four contract regions (CR-6 to CR-9) served by the STA reveal much higher supply per capita than some of the lower density contract regions such as CR-11. Moreover, some areas show significant growth in km supplied per capita of which CR-4 is perhaps the most startling. Network reviews (see Section 2.2) will also account for some of these observed differences. The implementation of the Service Planning Guidelines (NSW, 2006) has meant that generally, bus km supplied per capita in the contract regions operated by STA decreased over the 2005 – 2011 period, reflecting the planning aim of simplifying the comprehensive network. On the other hand, bus km per capita increased in regions run by private operators, reflecting the different emphasis on synthesising a legacy of multiple smaller networks.

**Figure 2 Annual bus service km per capita in each contract region (CR), 2005-2011**



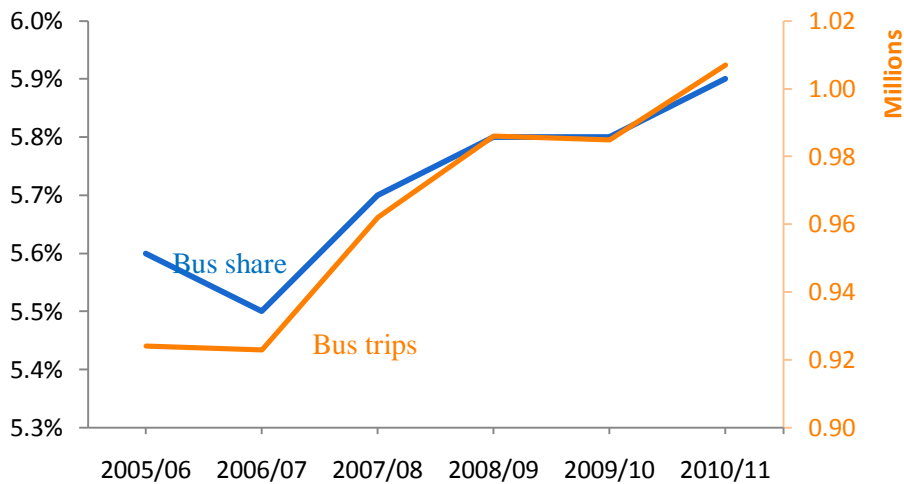
In Figure 2, population has been used to control for the effect of different size bus contract areas but other factors such as spatial layout (eg availability of rail) and socio demographics (eg age, car ownership etc) will also have an impact. Figure 2 is also based on km allocated to a contract region and not the km operated within a contract region boundary (with cross-regional routes being attached to the contract region of operation). Figure 2 is thus presented only to make some broad comparisons between contract regions, on the supply side.

### 3.2 Bus patronage

Data on monthly boardings for each contract region was also obtained from BTS. Other sources include annual reports from the State Transit Authority (STA), IPART submissions and fare determinations and NSW Auditor-General reports. Ideally data on bus user trips would be available and, in its absence, this section has used bus boardings as a proxy for patronage. Using bus boardings will over-estimate the number of trips, to the extent that a single trip uses more than one bus segment.

Broad aggregate trends on bus use can be seen from Figure 3, taken from the annual on-going Household Travel Survey (HTS) conducted by BTS in Sydney.

**Figure 3 Bus trips and mode share on an average weekday, Sydney Statistical Division**

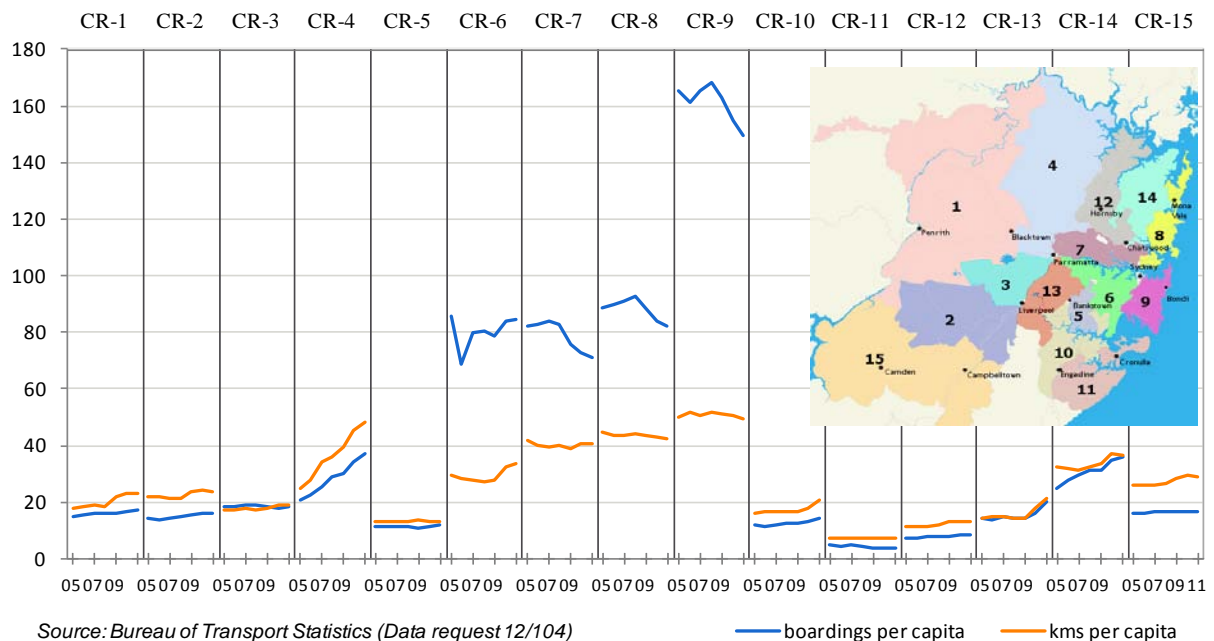


Source: Bureau of Transport Statistics (2011)

While the HTS sample size in individual contract regions is too small to accurately measure change in bus use over time, the HTS data provides an indication of changes in bus use in Sydney, relative to other modes, over the entire period considered by this paper. Figure 3 suggests a relatively constant increase in bus trips and bus share over the earlier period covered by this paper, from 2006-2009.

Monthly boardings data supplied by BTS are self-reported by operators into a number of categories, broadly covering multiple journey tickets (both off-board and on-board purchases), single tickets, non-fare paying and concessions tickets. Figure 4 shows both the annual boardings per capita and km supplied per capita for each contract region in the Sydney metropolitan area. Operators normally count boardings as fare paying passengers and so the free buses will not necessarily be captured in these totals systematically (even though their provision will be captured in service km).

**Figure 4 Annual bus boardings and bus service km per capita in each contract region (CR), 2005 – 2011**



Source: Bureau of Transport Statistics (Data request 12/104)

— boardings per capita — kms per capita

Concentrating on boardings, these are generally increasing, with the exception of contract regions 6, 7, 8, and 9 (operated by the STA). Comparing Figure 4 with Figure 3 suggests that there has been disproportionate increase in boardings in the contract regions operated by private bus operators. This may well reflect the way in which the significant policy and operational changes identified in Table 2 have more of an impact on private operators than on the STA (extension of the Pensioner Excursion Ticket to private bus services in and MyZone fares reform extending multi-modal options to private operator contract regions).

Figure 4 also shows that the inner Sydney contract regions (CR-6 to CR-9) have a different profile from the other contract regions. In the former, the boardings per capita are at least twice as high as the kms per capita reflecting the higher bus use and higher density of the operating area. In contrast, the other contract region areas typically have lower boardings per capita than kms per capita supplied. Three regions (CR-3, CR-13, and CR-14) appear to be more balanced in their demand and supply.

The aggregate profiles shown in Figure 4 show that outcomes in the contract regions are very variable. The next section considers each contract region in turn to examine specific events which affect kms supplied and boardings respectively.

#### 4. Individual contract areas

This section presents a graphical representation of monthly boardings (representing demand) and monthly kms operated (representing supply) for each of the contract regions individually. Figure 5 presents the four contract regions operated by the government STA. Figure 6 presents the remaining 11 contract regions operated by private operators. The figures show the change in boardings and kms over the month in which the contract was started. Both Figures 5 and 6 present a data series which is perhaps more variable than that might be expected (for both boardings and kms operated) and this is most likely due to the use of calendar month data where each month will include different proportions of weekday and weekend days, leading to varying monthly km totals even when the service offer has not changed. Note that the vertical scale (Y-axis) varies between the contract regions as each graph is scaled for the maximum and minimum values in the dataset.

Major events identified in Table 2 are embedded in Figures 4 and 5 to provide a visual connection with changes in bus boardings and kms supplied and these go some way to explaining the differences in performance of the more aggregate Figures 2 and 3. When looking at individual contract regions, data quality is potentially a greater issue. Whilst great care has been taken to use the data supplied, it needs to be remembered that data quality variation between operators will exist, since the data is self-reported.

Figure 5 considers contract regions operated by the STA (CR-6 to CR-9). For these contract regions, the change in boardings is typically greater than the change in km supplied each month. Thus, in relation to significant events, these can be regarded as a 'success' if the event is followed by an upward trend of the two series with the slope of the boarding series being steeper than that of the bus km supplied series (or the gap becoming wider, with change in boardings being greater than changes in km supplied). This is evident for Contract Region 6 after the introduction of the Funday Sunday ticket in 2008 and the expansion of the Metrobuses in 2011. Contract Region 7 presents a different profile with no noticeable success from significant changes, such as MyZone and the introduction of the two Metrobus routes (M52 and M54) specific to this area. Contract Region 8 has demand and supply that appears very much more in step with an increase in km being associated with a greater change in boardings. The network review and new network for Contract Region 9, as with Contract Regions 7 and 8, is associated with lower kms operated but the re-design appears to be successful since changes in boardings are positive with this event. Of the four government-operated regions, Contract Region 9 would appear to be performing best in terms of the reaction of boardings to significant changes in kms supplied.



**Figure 5 Changes (relative to the opening of the contract region) in boardings and km supplied for government operated services: 2005-2011**

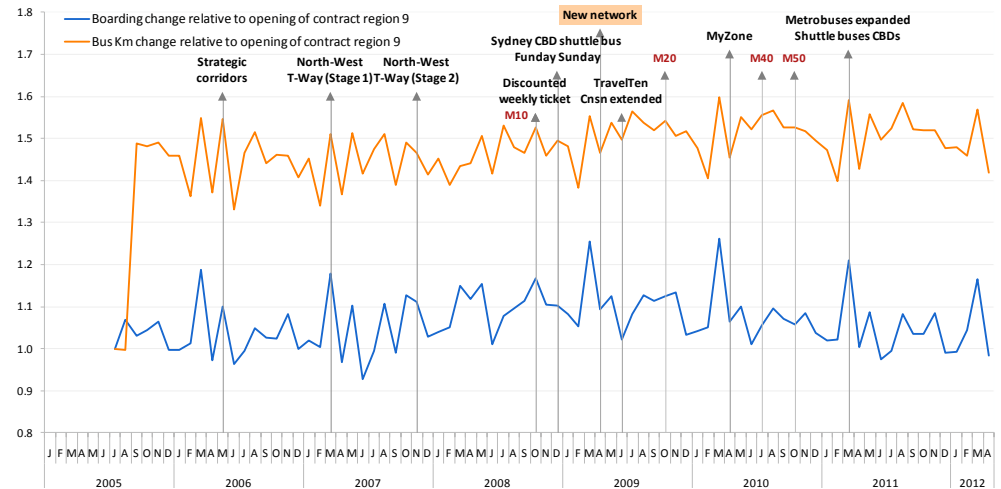
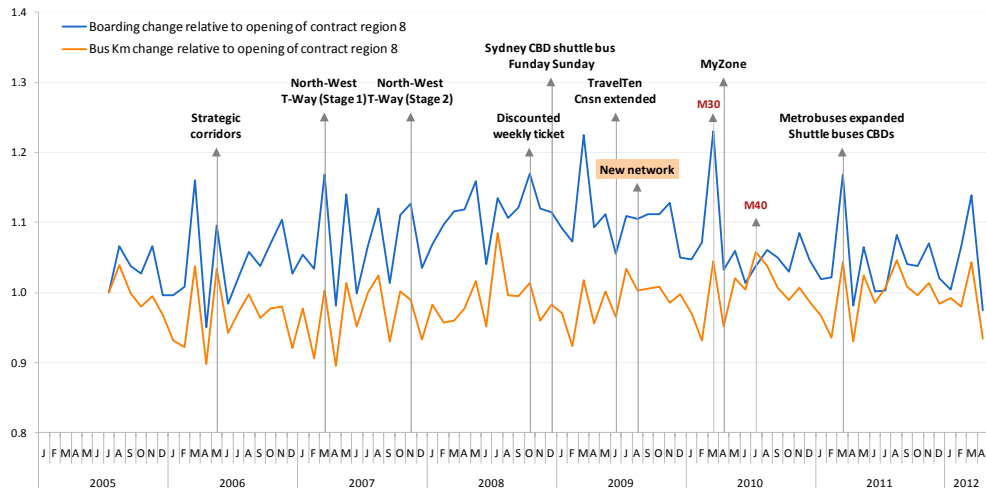
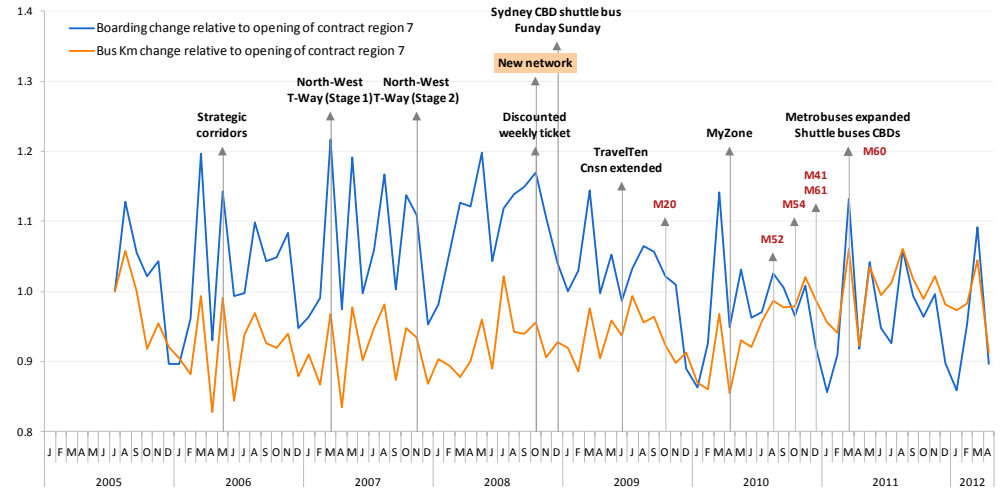
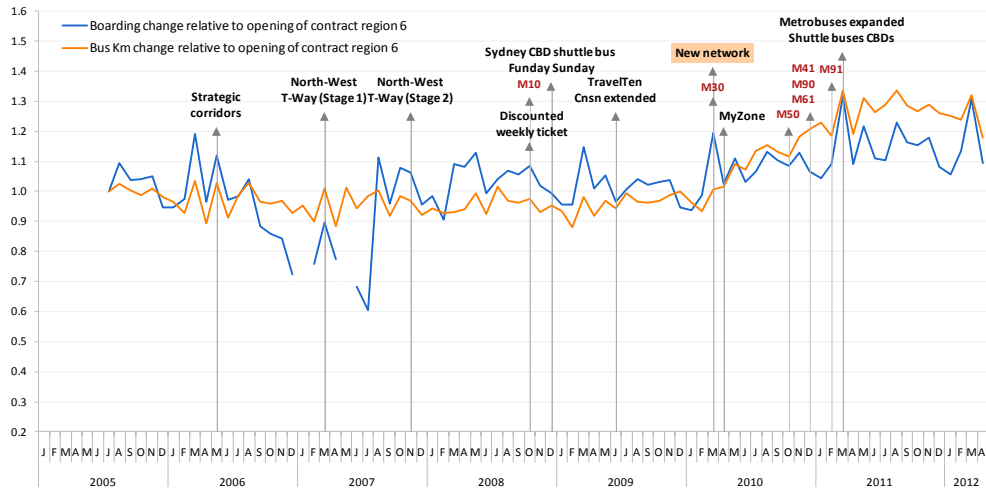


Figure 5 presents information for the remaining contract regions for the Metropolitan area of Sydney. What is immediately apparent is the great diversity between the contract regions. About half of these contract regions (Contract Regions 5, 10, 11, 12, 14 and 15) have a similar profile to the inner area served by STA (discussed above) with changes in boardings (above the base) being greater than changes in kms supplied.

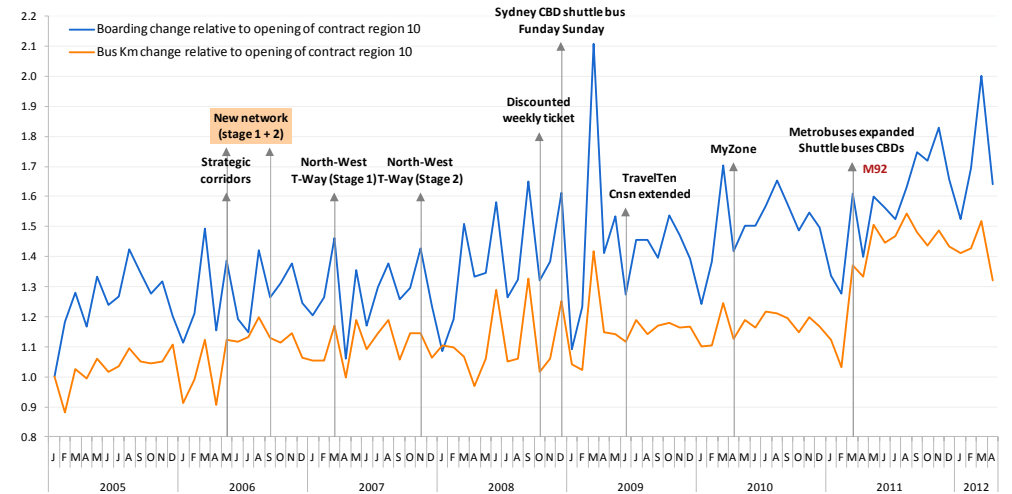
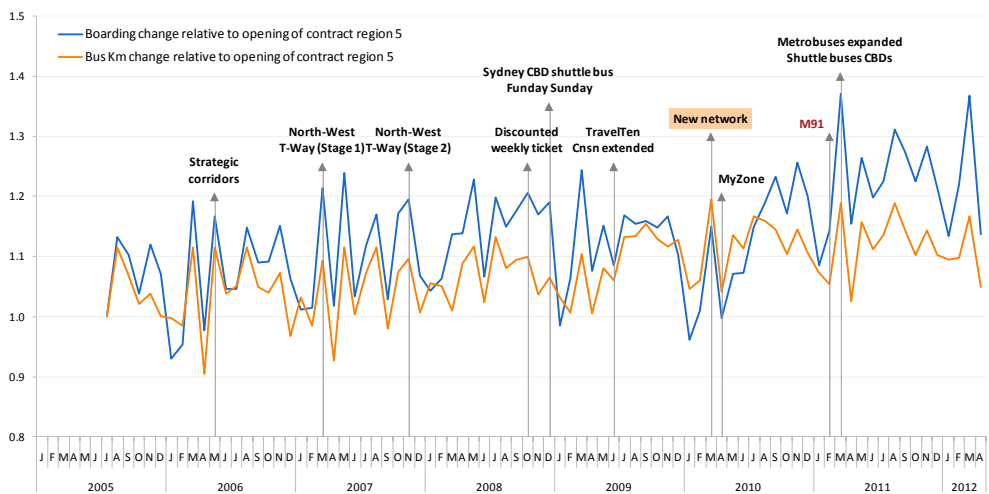
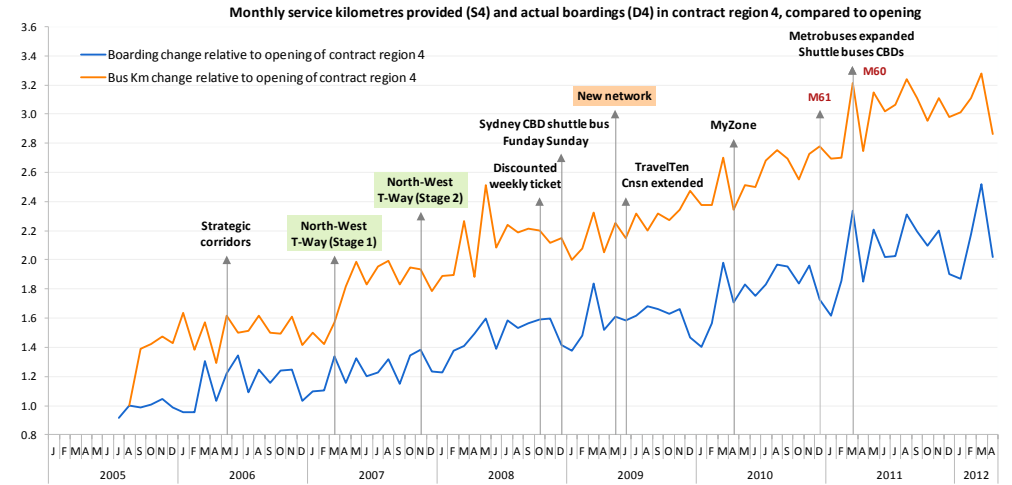
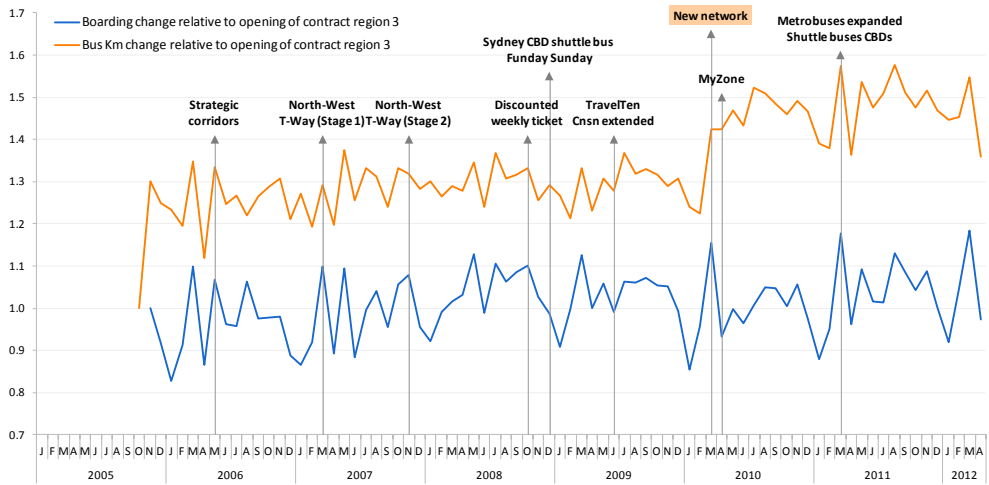
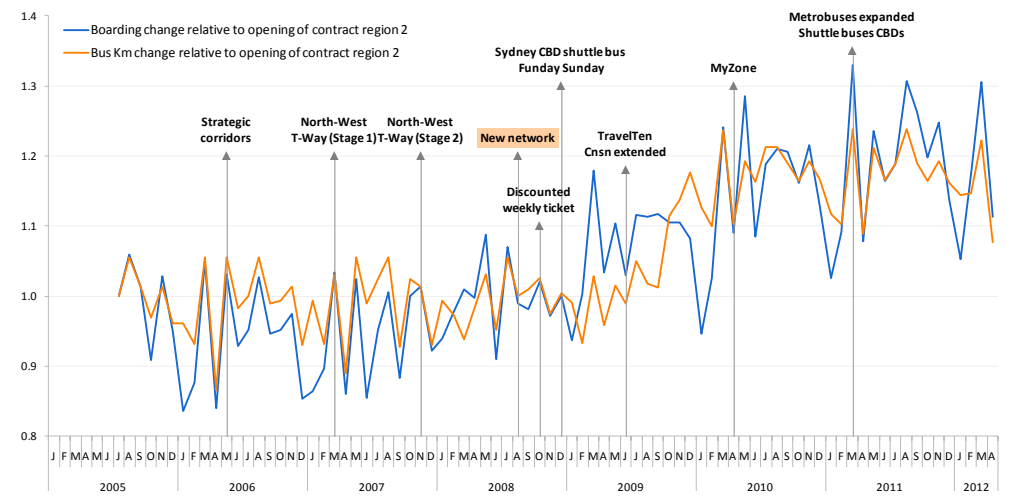
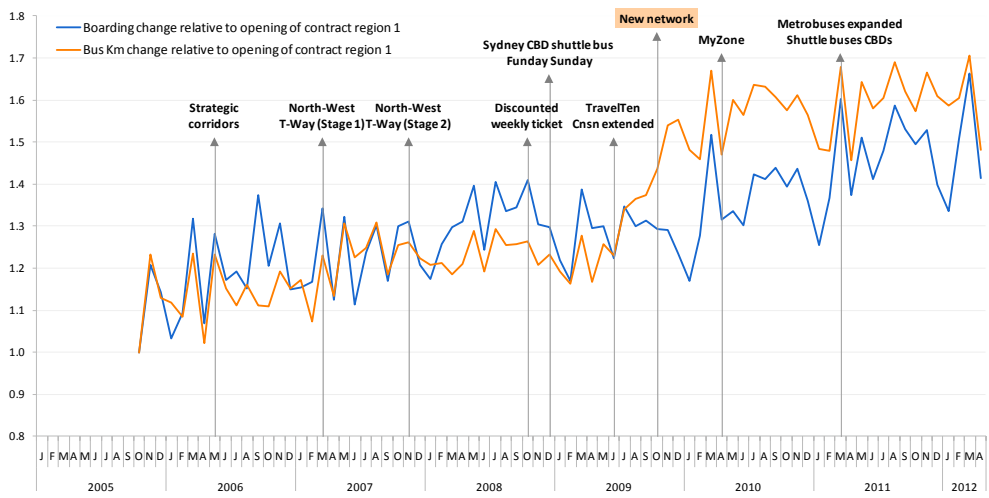
Of these, Contract Region 5 is a good example of how the positive effects of new network, closely followed by the introduction of MyZone led to greater changes in patronage than in supply. In Contract Region 10, the effect of the new network is not so marked but the impact of the extension of the travel ten opportunities and MyZone changes led to positive changes in patronage against an almost unchanged supply. This contract region also shows how care must be taken in the interpretation of the data. Metrobus M92, introduced in 2011, is operated by Contract Region 10 but passes through both Contract Region 10 and Contract Region 13. The graph shows the introduction of this route is associated with increases in km supply in Contract Region 10 and, although lagged in time, a positive impact on boardings. In this case the data for Contract Region 10 over-estimates the effect for this contract region since this is where both km and boardings are counted.

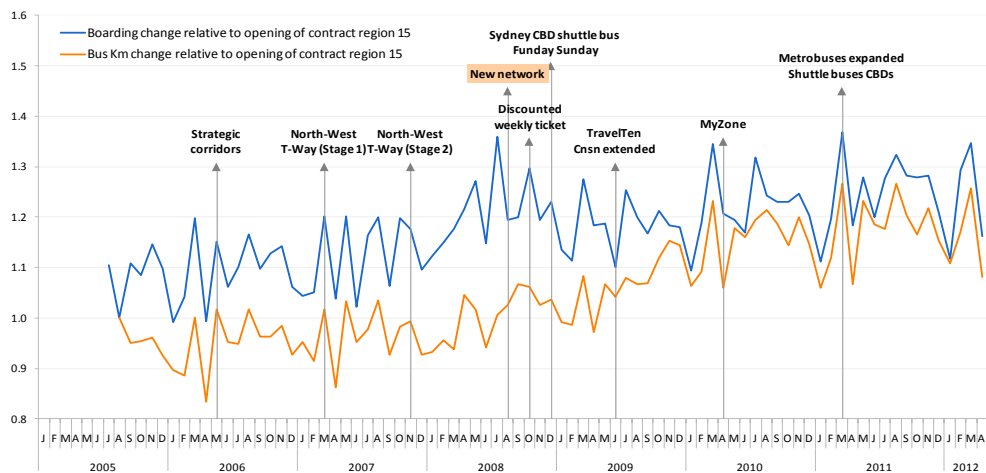
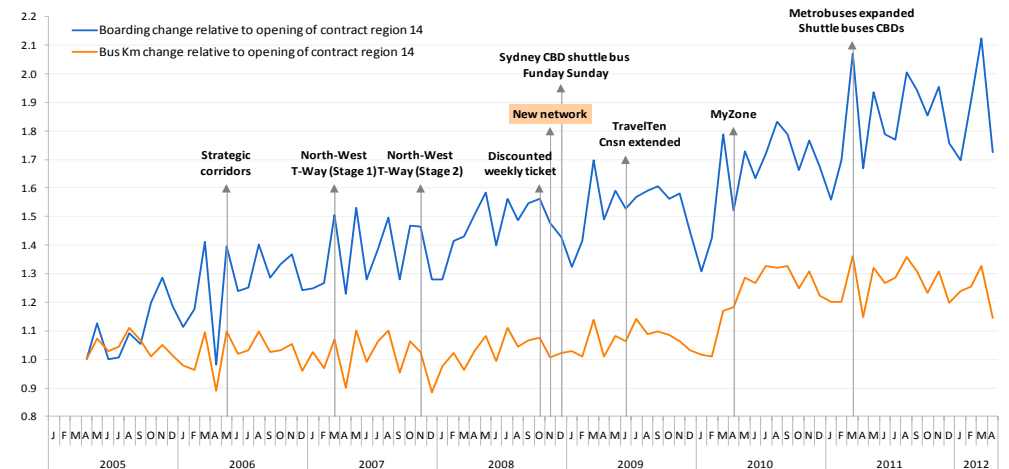
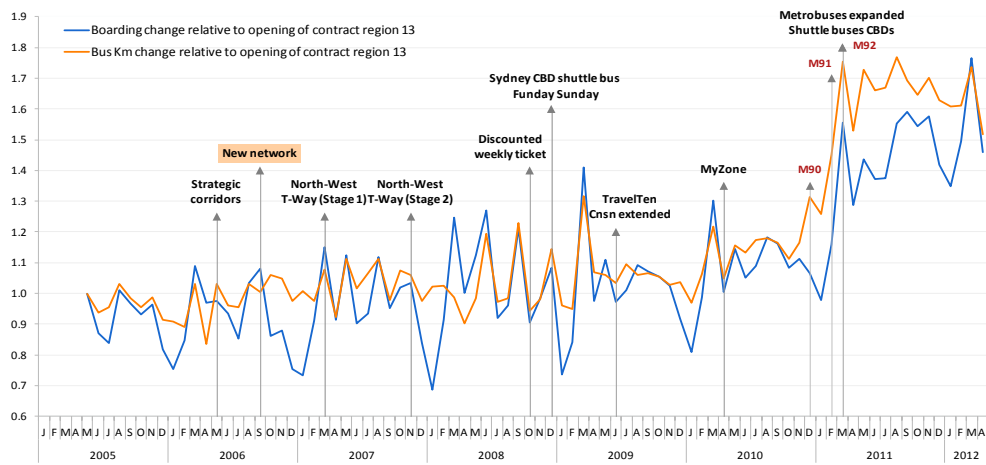
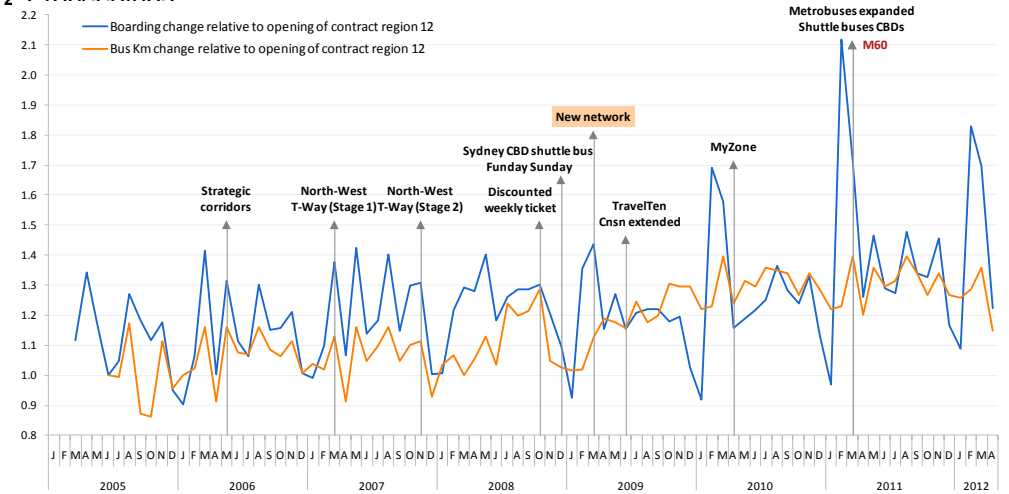
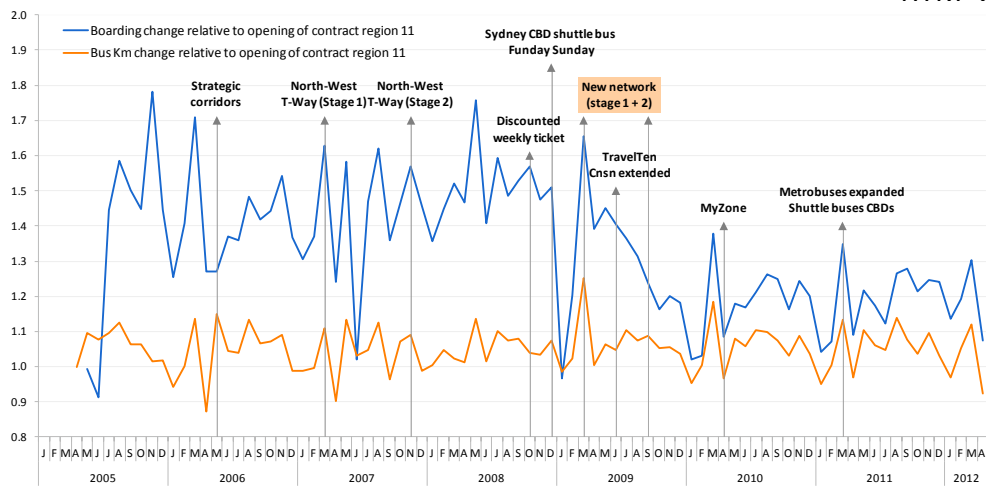
Contract Region 11 is an example of where the new network appears to have a negative impact on boardings. Bus km supplied is approximately constant throughout the time period but the change in boardings over the base sharply declined following the new network and does not recover. Contract Region 14, on the other hand, appears to have achieved increasing levels of boardings over the period. In this contract region, MyZone appears to have brought positive changes in boardings and this is corroborated by other evidence (Graham and Mulley, 2012). In contrast, Region 15 appears to have performed better in advance of its network review when bus km supplied were static but boardings increased. After the network review the reverse has occurred with bus km supplied increasing over the base and boardings remaining relatively static.

Contract Regions 3 and 4 show a different pattern with the change in km supplied over the base, being greater than the change in boardings. Contract Region 3 shows relatively static boardings over time with the new network being associated with increases in km supplied but without any corresponding increases in boardings. This contrasts with Contract Region 4 where changes in boardings over the base is lower than changes in km supplied but both series show an upward trend. In this contract region, the opening of the NW Transitway seems to have given a boost to the number of boardings. The network review was accompanied by an increase in supply of km and associated with a lower increase in boardings.

Contract Regions 1, 2 and 13 show similar patterns with changes in bus km and changes in boardings being similar over the period. Contract Region 2 shows that the network review was associated with both increases in km supplied and increases in boardings. In contrast, the network review in Contract Region 1 is associated with significant increases in km supplied but much lower changes in boardings, a pattern which is repeated in Contract Region 13.

The investigation of individual contract regions alongside significant or major events has highlighted a number of common factors. Evident in most of the contract regions is the time lag between changes in supply and changes in boardings. The analysis has also highlighted similarities between contract regions in terms of the km supplied and boardings characteristics. To a certain extent, some of the differences can be attributed to whether the contract region has a 'bus friendly' environment with higher densities such as the areas served by the STA. It might be expected therefore that the fringe areas might be less conducive to successful bus operation and yet a number of contract regions are showing significant success at growing patronage.





**Figure 6 Changes (relative to the opening of the contract region) in boardings and km supplied for privately operated services: 2005 – 2011**

However, this analysis suffers from the serious limitation of considering two separate series of data which cannot take account of the way in which some contract regions are larger than others, nor the way in which the significant events might impact differently in the different regions since they occur at different times and in different combinations. The next section models the connection between boardings and km supplied, taking these factors into account.

## 5. Multivariate modelling of impacts

This section examines the impact of network planning and policy changes on bus demand in the whole Sydney Metropolitan area using a multivariate regression analysis approach. This provides the opportunity to take account of the major events discussed in previous sections and investigate whether these have different impacts on different contract regions, after controlling for size and operator.

**Table 4 GLS regression model of log monthly total bus boardings per capita**

Variable	Coefficient	Standard Error	Standardised coefficient	t-stat	VIF
<i>Log (kms per capita) * STA</i>	1.617	.032	.813	50.82	3.2
<i>Log (kms per capita) * PRIVATE</i>	1.147	.027	.560	42.77	3.3
<i>Population density ('000s/km<sup>2</sup>)</i>	.079	.007	.202	12.05	3.5
<i>MyZone * STA</i>	-.024	.016	-.019	-1.54	4.6
<i>MyZone * PRIVATE</i>	-.027	.009	-.034	-2.97	2.3
<i>North-West Transit Way * CR-4</i>	.005	.024	.003	.20	2.8
<i>New network, CR-1</i>	-.001	.025	.000	-.03	1.3
<i>New network, CR-2</i>	-.019	.022	-.009	-.83	1.3
<i>New network, CR-3</i>	.015	.026	.006	.57	1.3
<i>New network, CR-4</i>	-.020	.028	-.009	-.71	2.5
<i>New network, CR-5</i>	-.077	.027	-.031	-2.80	1.5
<i>New network, CR-6</i>	.065	.027	.027	2.39	2.3
<i>New network, CR-7</i>	-.026	.026	-.011	-1.03	2.1
<i>New network, CR-8</i>	.005	.026	.002	.21	2.1
<i>New network, CR-9</i>	.004	.025	.002	.18	2.1
<i>New network, CR-10</i>	-.068	.019	-.038	-3.53	1.2
<i>New network, CR-11</i>	-.036	.024	-.016	-1.48	1.7
<i>New network, CR-12</i>	-.048	.023	-.022	-2.07	1.3
<i>New network, CR-13</i>	.021	.020	.011	1.05	1.3
<i>New network, CR-14</i>	.077	.023	.036	3.27	1.5
<i>New network, CR-15</i>	-.082	.023	-.039	-3.59	1.4
Constant	-.202	.01		-16.49	

$\bar{R}^2 = 0.87$  ( $p < 0.001$ ).  $N = 1,204$

The adjusted  $R^2$  of the final model is 0.87, meaning that the set of independent variables explains 87 percent of the variation of the log of monthly bus boardings per capita. Multicollinearity or the presence of linear correlation among the explanatory variables is confirmed as not being an issue for the model as indicated by the VIF (last column of Table 4) that are all smaller than a rule-of-thumb value of 5.0.

The estimated coefficient show that bus km supplied per capita has a significant positive relationship with bus boardings per capita, and this effect is much stronger in the contract regions operated by STA than in the regions covered by private operators (see *standardised*

*coefficient* column in Table 4 where the standardised coefficient is larger for the STA contract regions). Because the model represents the relationship between log monthly boardings per capita and log monthly km supplied per capita, care must be taken to interpret the coefficient estimates. For instance, a monthly increase of 10 km per capita on the supply side would lead to 41.4 more boardings per capita per month ( $10^{1.617} = 41.4$ ) if the increase is in the STA regions and 14.0 ( $10^{1.147}$ ) more boardings per capita per month if the increase is in the areas served by private operators.

Population density is confirmed as an important predictor of bus boardings with dense regions showing a higher boarding rate. The results suggest that an increment of 1,000 people per km<sup>2</sup> in contract regional population density would increase bus boardings per capita by 20 percent.

The introduction of MyZone tickets on bus demand is insignificant in regions operated by STA but is highly significant in regions served by private operators. The results are consistent with expectation as MyZone fares reform had more impact on private operators. In interpreting the negative coefficients associated with the interactions terms between MyZone and the separate contract areas, it must be remembered that the dependent variable is transformed to logarithmic base so the introduction of MyZone fares which have a coefficient of -0.027 means that the introduction of MyZone fares brought on average  $10^{-0.027} = 0.94$  more boardings per capita in areas served by private operators.

The effect of the opening of the North-West T-Way on bus boardings, even in the most relevant area of Contract Region 4, is not significant suggesting that the opening of the North-West T-Way does not have any other effect on the number of boardings apart from the effect which results from an increase in bus km supplied.

Of the 15 contract regions commenced with new services, some network planning changes result in an increase in the number of bus boardings. Overall, the bus reform package implemented in Contract Regions 5, 6, 10, 12, and 14 significantly increases bus boardings over and above the additional bus km supplied. It should be noted that the estimated effect of changes in network planning on bus use includes other changes to the network such as the number of Metrobuses either operated or run through but not operated by the contract region, and other events which occur after the introduction of the new network. Including these events alongside the variable for the new network in the single model created serious multicollinearity problems.

## 6. Conclusions

The efficient use of government resources in the provision of public transport is important and this research has implications for transport and wider policy within NSW with the recognition that public transport accessibility plays a key role in economic sustainability and growth.

This evaluation of the bus reform introduced from 2005 has highlighted a number of issues.

First, there appears to be noticeable differences in the supply of bus km and the boardings in contract regions operated by the STA and those operated by the private operators. Typically, in the STA contract regions boardings per capita exceed kms supplied per capita and do so by a significant margin. In the contract regions operated by private operators the reverse is typically true, although the patterns are more mixed.

Second, in looking at performance over time on an individual contract area basis, there are distinctive patterns which emerge from the impact of significant events. The network reviews, introduced as part of the bus reform, do not always appear to boost patronage, given changes in supply. Indeed, the examination on an individual contract area basis suggests that there is variation in performance that must be attributable to good and poor operator performance and network planning.

Finally, the multivariate modelling identifies that it is primarily the quantity of kms supplied which influence boardings. However, the modelling shows quantitatively the way in which, over and above the kms supplied, the network review had a significant effect on boardings in a number (but not all) of the contract areas.

The way in which network reviews and operator performance might be significantly affecting the level of boardings requires further research. In particular, a detailed investigation of the network review and the extent to which 'good network planning' was put in place needs identifying. For operators, further variables which are known to affect demand for public transport, such as the speed of travel might improve the predictive nature of the model.

Future research needs to examine boardings in more detail, specifically to identify whether changes to the network have led to disproportionate increases or decreases in particular customer segments as a way of identifying the distributional impacts of change.

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