APPRAISAL OF FACTORS INFLUENCING PUBLIC TRANSPORT PATRONAGE IN NEW ZEALAND

Judith Y T Wang[1]

The Energy Centre

The University of Auckland Business School

Private Bag 92019, Auckland, New Zealand

ABSTRACT

This paper examines the demand for local bus and rail services in the three major regions in New Zealand: Auckland, Wellington and Canterbury. In order to determine the drivers behind the changes in public transport ridership over time, econometric analysis techniques were applied to analyse the time-series data collected for the last decade. A dynamic model was identified for each region by mode relating per capita patronage to fares, service level, car ownership, income and fuel price. The results indicated that the three cities all have different characteristics and the drivers behind the long-run and short-run trends were also different. It also appeared that the significant fluctuation in fuel price in recent years did have a positive effect on public transport patronage in all three cities.

Keywords: public transport demand forecasting, time series data analysis, elasticities

1 INTRODUCTION

Booz & Company (formerly Booz Allen Hamilton) was commissioned by New Zealand Transport Agency (NZTA) in April 2006 to carry out econometric research into the impact of transport fuel price changes (BAH, 2006). Econometric analysis of the impact of petrol prices in New Zealand (NZ) was conducted on the following three demand variables:

(1) petrol consumption;

(2) highway traffic volumes; and

(3) public transport (PT) patronage.

From this previous study, statistically significant estimates of the first two direct elasticities were obtained successfully relating petrol price changes to petrol consumption and highway traffic volumes. However, the cross-price elasticity of public transport patronage with respect to petrol prices could not be estimated with a satisfactory level of significance. Although by intuition one would expect that petrol prices might have a certain level of influence on public transport patronage, it is clear that there are other factors with more

[1] This research was carried out when the author was affiliated with Booz & Company. The author is currently affiliated with The Energy Centre at The University of Auckland Business School. Email address j.wang@auckland.ac.nz

significant influences which were not considered in the previous study.

Booz & Company was commissioned in 2007 by NZTA to extend this research to include in-depth analysis of public transport patronage. The objectives of this study are as follows:

(1) to identify the key factors affecting public transport patronage;

(2) to estimate the elasticities with respect to each of the key factors identified; and

(3) to develop forecasting models for use by transport operators and transport funding agencies.

We explored trends in public transport patronage and identified key factors that might have contributed to those trends. Econometric models were applied to estimate the relationships between public transport patronage and key factors and hence estimate elasticities for each of the key factors identified.

The analysis was based on annual and quarterly national and regional aggregate data for three major regions in NZ over the last decade as follows:

(1) Auckland - Quarterly from 1996 Q1 to 2008 Q2

(2) Wellington - Annually from Financial Year 99/00 to 07/08

(3) Canterbury - Quarterly from 1997 Q1 to 2008 Q2

2 LITERATURE REVIEW

The literature review for this study was undertaken with two main areas of focus: (1) to ascertain different methodologies; and (2) to enable a comparison of results from this study with international experience. In this section, we focussed on the different methodologies applied in patronage demand analysis. In addition, recent studies on the determinants of the demand for public transport, including a study on public bus ridership in Auckland conducted by Greer (2008) of the Energy Centre of the University of Auckland based on the latest Census 2006 data, were also reviewed. Results from international experience are discussed in Section 4.2.

For more than 50 years, extensive effort has been devoted in the world of research and practice to analysing the impact of changes in fares, service supply, income and other factors on the demand for public transport. The key techniques applied in estimates of public transport elasticities can be categorised as follows:

(1) Empirical analysis – e.g. Litman (2004), Goodwin (1992) and Oum et al (1992) provide some classic reviews of empirical evidence from studies taken prior to 1990.

(2) Stated preference (SP) or combined Revealed preference (RP)/ SP – e.g. Espino et al (2007), Hensher and King (1998).

(3) Econometric analysis – e.g. Bresson et al (2003), García -Ferrer et al (2006)

The most relevant study to this research project is a study commissioned by the Department for Transport of U.K. in 1998, conducted by Dargay and Hanly (2002a and 2002b). The main aim of the project was to obtain fare elasticity estimates for use in policy calculations of the projected change in bus patronage from a given average change in fare. The analysis was based on annual national and regional data. The data for Great Britain as a whole covered the financial years 1974/75 to 1996/97 whereas data for the regions was limited to the periods 1986/87 to 1996/97. Time series analyses were conducted to take into account the intertemporal nature of the data being used. The basic model developed relates per capita bus patronage (all journeys) to real per capita income, real bus fares and service level (bus vehicle kilometres). In addition, a structural model was estimated to test the interaction of bus patronage, motoring costs and car ownership.

Around the same time, a French research project (Madre and Boulahbal (1999), Bresson and Pirotte (1999)), financed by VIA-GTI and the Department of Transport, was conducted to investigate the effect on public transport use of changes in population structure, urban sprawl and increasing car ownership. Unlike the British study, which was only concerned with bus travel, the French study covered all public transport modes for urban travel. Bresson et al (2003) combined the data collected for the two projects, i.e. on the basis of panels of English counties and French urban areas, to analyse the impact of changes in fares, service supply, income and other factors on the demand for public transport. The analysis was based on dynamic econometric models so that both short- and long-term elasticities could be estimated.

More recently, a Spanish research project, financed by Comunidad Autónoma de Madrid, was carried out by García-Ferrer et al (2006) to analyse data on the choice of alternative public transport modes in the Madrid Metopolitan Area. Monthly data were obtained and econometric analysis was applied to estimate the users' response to changes in prices and characteristics of the services so a more reliable prediction of demand could be obtained. As in other studies in the literature, dynamic econometric modelling techniques were applied in order to capture the nonstationary characteristics of the data.

Bresson et al (2004) explored the economic and structural determinants of the demand for public transport based on a panel data analysis of annual time series from 1975 to 1995 for 62 urban areas in France. Three economic determinants were considered − vehicle-kilometres, income and price. Public transport was found to be an "inferior good" as the estimated income elasticity was negative. By synthesising the structural determinants (including population ageing, urban sprawl and growing car ownership) in a single indicator, there was an interesting discovery that the "income effect" was in fact mainly a "motorisation effect". It was concluded that the downward trend in public transport patronage is mainly due to increasing car ownership. It was also observed that the use of public transport is quite sensitive to the service level and to its price.

Hensher (2008) analysed the direct elasticities associated with public transport demand with respect to changes in three factors: fares, in-vehicle time and headway, based on information from 319 studies. The major influences identified were: time of day (peak, all day versus off-peak), data paradigm (especially combined Stated Preference (SP)/Revealed Preference (RP) versus RP), whether an average fare or class of tickets was included, the unit of analysis (trips versus vehicle-km), specific trip purposes, country and specific-mode (i.e. bus and train).

Greer (2008) carried out a spatial analysis of cross-sectional data on bus ridership by commuters to work and other related statistics for the Auckland region collected during the census 2006. The results from a regression analysis indicated that the following four factors had a positive effect on commuter bus ridership:

(1) the total number of commuters from the area unit;

(2) the distance from the centre of the area unit to the nearest rail or ferry terminal;

(3) the population density of the area unit; and

(4) the combined morning and evening peak hour bus service frequency within the area unit.

On the other hand, the following three factors were found to have negative influence on commuter bus ridership:

(1) the average number of cars available to a household within the area unit;

(2) the distance from the centre of the area unit to the city centre; and

(3) median household income within the area unit.

3 THE MODEL

The historical trends of public transport patronage for the last decade were explored. The stories behind the changes in trends were revealed and the influencing factors that might have contributed to the changes were identified. A short-term and long-term forecast model was determined for each major transport mode in each region. Six variables were considered in the model as follows:

Dependent variable

(1) Patronage (in trips per capita)

Economic determinants

(2) Service level (in bus/train kilometres per capita)

(3) Real fare (in real revenue per passenger)

(4) Real income (in real disposable income per capita)

Structural determinants

(5) Car ownership (in cars per capita by region)
(6) Real fuel price

A Partial Adjustment Model was developed for each mode in each of the three cities. The idea behind the PAM is that an individual's travel behaviour to a certain extent is a habit. One's choices today have an effect on one's future decisions. This is modelled by introducing a lagged independent variable on the right-hand-side of the equation and the associated adjustment coefficient. The model specification is detailed in the Appendix.

4 RESULTS

Model estimation was implemented with the Dynamic Linear Regression R-package developed by Zeileis (2009). As the objectives of this study were to identify the factors influencing public transport patronage in NZ and estimate the demand elasticities with respect to the factors identified, the results were compared with international experiences in a twofold manner:

(1) to compare which factors were influencing public transport patronage; and
(2) to compare the estimated elasticity values.

4.1 Influencing Factors

Table 1 Summary of factors influencing public transport patronage in NZ

	Auckland		Wellington		Canterbury Bus
	Bus	**Rail**	**Bus**	**Rail**	
Service	positive	positive	n/a	positive	positive
Fare	n/a	negative	negative	n/a	negative
Car Ownership	negative	n/a	n/a	negative	n/a
Income	n/a	positive	n/a	negative	n/a
Fuel Price	positive	n/a	n/a	positive	positive

The influencing factors identified are depicted in Table 1.

4.1.1 Service and fare

Litman (2004) found in his review that PT fares, service quality (service speed, frequency, coverage and comfort), and parking pricing tend to have the greatest impact on PT patronage. It appeared from our findings that both service and fare did have a significant effect in all three cities although not on all modes. It is important to note that fare was not a significant factor influencing bus demand in Auckland. Litman (2004) found that large cities tend to have lower price elasticities than suburbs and smaller cities as they have a greater portion of PT-dependent users. Auckland has always been the largest among the three regions with more than one third of the population in the country. We would expect that Auckland should definitely have a bigger proportion of PT-dependent users in the region, for instance, international students, new immigrants, etc. This could be a reason why fare was found to be an insignificant factor affecting the bus patronage which has always been the major public transport mode in Auckland.

4.1.2 Differences between modes and cities

Litman (2004) also found that bus and rail often had different elasticities because they served different markets. In our case, it appeared that bus and rail had different influencing factors for the same reason. For example, in Wellington, fuel price was found to be an influencing factor for rail but not for bus. On the contrary, in Auckland, fuel price was found to be an influencing factor for bus but not for rail. We believe that this could be evidence of a strong substitution effect between car and bus in Auckland; and between car and rail in Wellington.

This hypothesis was also supported by the observation that car ownership was found to have a significant effect on Auckland bus and Wellington rail patronage. On the other hand, the influence of car ownership on bus patronage in Canterbury was found to be insignificant. We believe that a possible explanation is that Canterbury had the highest car ownership level among the three cities. As mentioned in Dargay and Hanly (2002b), the analysis on bus patronage in England showed that the overall picture could be quite different as car ownership became saturated. If the car ownership in Canterbury was saturated, the decision of whether to take the bus or not would more likely to be influenced by factors other than car ownership. Thus, our study results indicated that service, fare and fuel price had significant influence.

4.1.3 Car ownership and income

Among the five influencing factors that we considered, namely, service, fare, car ownership, income and fuel price, two out of the five factors, 'car ownership' and 'income', never entered into any models for the three cities at the same time. This was similar to the experience in France as described in Bresson et al (2004). A model was first estimated using the entire set of explanatory variables, including disposable income, a structural indicator (representing the effect of changes in population characteristics, urban sprawl and car ownership), the PT fare, three service measures (seat-kilometres per capita, service frequency and network density) and fuel price. The income variable was dropped as it was found to have an insignificant effect on patronage. It was not surprising that income was a major determinant of car ownership. One would expect that car ownership and income are positively correlated and hence should not be both included in the equation at the same time anyway.

In our case, the car ownership effect was found to have significant negative effect for Auckland bus and Wellington rail. On the other hand, income was found to have positive effect on Auckland rail. It was found generally in the literature, such as Bresson et al (2003) and Dargay and Hanly (2002a, 2002b), etc. that the income effect was negative rather than positive. Nevertheless, as stressed in Dargay and Hanly (2002b), negative income elasticity pertained to a period of rising car ownership and use. It is likely that the income effect could become positive rather than negative when the use of private vehicles approaches saturation.

4.2 Elasticities

Litman (2004) provides a comprehensive review on elasticities for public transport planning in the literature including the classic reviews by Goodwin (1992) and Oum et al (1992). In this section, we compare our results to the relevant studies in the literature.

4.2.1 Service Elasticity

The estimated bus and rail service elasticities in Auckland, Wellington and Canterbury are depicted in Table 2 and Table 3. As compared to study results from England, our estimate of a short-run service level elasticity for bus service in Auckland of 0.46 was comparable with that for bus services in England of 0.49 as shown in Table 4. Our estimate of a long-run service level elasticity of 0.73 was also comparable with that for England of 0.77, as shown in Table 5.

On the other hand, our short-run estimate of 0.07 for Canterbury bus service appeared to be much lower as compared to the estimates of 0.57 and 0.29 for England and France respectively, as shown in Table 5. On the other hand, our long-run estimate of 0.62 is similar to the long-run estimate of 0.57 in France as shown in Table 5. We believe that one possible explanation is the high car ownership in Canterbury, which was the highest among all the three cities. Whether to take the bus was more of a long-term decision rather than short-term which was decided together with car ownership decision at the same time. Thus the service elasticity in Canterbury appeared to be lower than international experience.

Both Auckland and Wellington rail had very high short-run and long-run service elasticities; short-run in the range of 0.88-0.99 in Auckland and 0.74-0.78 in Wellington; long-run in the range of 1.41-1.63 in Auckland and 2.39-2.53 in Wellington. They were much higher than the estimates of 0.29 (short-run) and 0.57 (long-run) in France as shown in Table 5. Moreover, only the long-run estimates were consistent with the expectation of higher elasticities for smaller cities. We believe that this could be due to the service kilometres of rail service in Auckland being measured in train kilometres which was not a precise measure of service level as the train composition could vary from 2-car to 6-car depending on time of the day and day of the week. Thus the estimates for Auckland could be overestimated. The fact that bus and rail served different markets could also be another reason.

Table 2 Bus demand elasticity estimates in Auckland, Wellington and Canterbury

	Auckland 2003Q3-2008Q2		Wellington		Canterbury	
	short-run	long-run	short-run	long-run	short-run	long-run
Bus Service	0.46	0.73	n/a	n/a	0.07	0.62
Bus Fare	n/a	n/a	-0.23	-0.46	-0.26	-0.34
Car Ownership	-1.96	-3.10	n/a	n/a	n/a	n/a
Income	n/a	n/a	n/a	n/a	n/a	n/a
Fuel Price	0.20	0.32	n/a	n/a	0.28	0.37

Table 3 Rail demand elasticity estimates in Auckland, Wellington and Canterbury

	Auckland				Wellington			
	short-run		long-run		short-run		long-run	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
Rail Service	0.99	0.88	1.41	1.63	0.74	0.78	2.39	2.53
Rail Fare	-0.97	-0.68	-1.37	-1.25	n/a	n/a	n/a	n/a
Car Ownership	n/a	n/a	n/a	n/a	-0.32	n/a	-1.04	n/a
Income	1.61	n/a	2.28	n/a	n/a	-0.22	n/a	-0.70
Fuel Price	n/a	n/a	n/a	n/a	0.13	0.12	0.42	0.39

Table 4 Estimated elasticities for bus services in England

Variable	Estimated Elasticity
Journeys(-1)	0.52
Income	-0.39
Service	0.49
Motoring Costs	0.32
Percent Pensioners	-0.08
Fare	-0.33

Source: Dargay and Hanly (2002a), Table 1

Table 5 Public transport elasticities in England and France

	Estimated Elasticities Using Shrinkage Estimators in a Log-log model					
	England[a]			France[b]		
	Service	Fare	Income	Service	Fare	Income
Short-run	0.57	-0.51	-0.67	0.29	-0.32	-0.05
Long-run	0.77	-0.69	-0.90	0.57	-0.61	-0.09

Note: [a] The main objective was to estimate bus elasticities based on time-series data for different regions and for a panel of 46 English counties (urban and rural).
[b] The French study includes all public transport modes for urban travel and covers a sample of 62 out of about 100 urban areas.
Source: Bresson et al (2003)

4.2.2 Fare Elasticity

The estimated bus and rail fare elasticities in Auckland, Wellington and Canterbury are depicted in Table 2 and Table 3. Litman (2004) found that large cities tend to have lower price elasticities than suburbs and smaller cities as they have a greater portion of PT-dependent users. The estimated resident population in the three regions in 2008 based on our data imputation model are as shown in Table 6.

Table 6 Estimated national and regional resident population

	Estimated Population	As Percentage of National Population
NZ	4,268,650	
Auckland	1,435,645	33.63%
Wellington	475,944	11.15%
Canterbury	554,442	12.99%

Source: Imputation based on NZSTAT

Table 7 Bus fare elasticities versus size of city

	Large Cities (More than 1 Million Population)	Smaller Cities (Less than 1 Million Population)
Average for all hours	-0.36	-0.43
Peak hour	-0.18	-0.27
Off-peak	-0.39	-0.46
Off-peak average	-0.42	
Peak hour average	-0.23	

Source: As cited in Litman (2004) from Pham and Linsalata (1991)

Table 8 Elasticities estimated on basis of structural model of bus and automobile use, national Great Britain data

	Bus Passenger-km	Bus Journeys	Car Ownership	Car Passenger-km
Car ownership				
Short-run	0	0		0.94
Long-run	-0.73	-0.64		0.81
Bus fare				
Short-run	-0.31	-0.52	0.19	0.18
Long-run	-0.94	-1.08	0.42	0.34
Income				
Short-run	0.14	0.38	0.37	0.14
Long-run	0.07	-0.26	0.56	0.70
Motoring costs				
Short-run	0	0	-0.38	-0.44
Long-run	0.37	0.33	-0.51	-0.96

Source: Dargay and Hanly (2002b)

Comparing the estimated long-run bus fare elasticity of -0.46 in Wellington and -0.34 in Canterbury with international statistics as shown in Table 7, it appeared that our estimated value of -0.46 for Wellington was comparable with the average for all hours estimate of -0.43 for smaller cities with less than 1 million population as shown in Table 7, but the estimated value of -0.34 in Canterbury was lower than expected. Nevertheless, both values were within the range of most typical elasticity estimates of -0.1 to -0.6 in Oum et al (1992) but slight less than the estimate of -0.55 in Table 3 of Goodwin (1992).

Our model structure was very similar to the model in Dargay and Hanly (2002a). The major difference was in how we applied the model. Dargay and Hanly (2002a) applied the model to annual bus data in England by county. Because the availability of data per county was very limited – only 10 annual observations – they pooled the data together and developed a pooled model for all counties. Our estimate of the short-run bus fare elasticity in Wellington of -0.23 was less elastic than the overall short-run fare elasticity of -0.33 of England, as shown in Table 4. On the other hand, the short-run bus fare elasticity in Canterbury of -0.34 was comparable with the values of -0.33 in England, as shown in Table 4, and -0.32 in France, as shown in Table 5.

In terms of rail fare elasticities, our short-run and long-run estimates for Auckland were in the range of -0.68 to -0.97 and -1.25 to -1.37, respectively. As compared to the French study as shown in Table 5 of -0.32 and -0.61, our estimates for Auckland were much higher. We believe that this could be the effect of significant increase in rail fare of 10% in February 2006 plus another 15% in January 2007.

4.2.3 Car Ownership Elasticity

The estimated car ownership elasticities of bus and rail demand in Auckland, Wellington and Canterbury are depicted in Table 2 and Table 3.

Dargay and Hanly (2002b) developed a structural model to examine the influences of income, bus fares, car ownership and use and motoring costs on bus patronage in England. As shown in Table 8, the estimated short-run and long-run elasticities of bus journeys with respect to car ownership are 0 and -0.64 respectively. We could not really compare our results with these estimates directly because both car ownership and car passenger-km were considered in Dargay and Hanly (2002b) while we considered only car ownership. In other words, we were trying to measure car ownership and its use with only one variable. We believe that this is why our estimated values of -1.96 (short-run) and -3.10 (long-run) for Auckland bus, and -0.32 (short-run) and -1.04 (long-run) for Wellington rail, were much higher in magnitude, especially for Auckland bus, as compared to their estimates.

4.2.4 Income Elasticity

The estimated income elasticities of rail demand in Auckland and Wellington are depicted in Table 3 but there were no reliable estimates of income elasticities of bus demand from our results.

As discussed earlier, the income effect was found to be negative in most studies in the literature, such as Bresson et al (2003) and Dargay and Hanly (2002a, 2002b). In this study, the estimated income elasticities of rail demand in Auckland were positive, 1.61 (short-run) and 2.28 (long-run), while the estimates for Wellington rail were negative, -0.22 (short-run) and -0.70 (long-run). We believe that this was due to the difference between the two markets. Auckland rail had gone through tremendous improvement during the study period while Wellington rail was a well established mature system. In Auckland, the share of commuters in the rail market increased significantly since the opening of Britomart with CBD being within walking distance from the new station. The newly attracted commuters would have characteristics such as higher income. Thus the elasticity estimates for Auckland were positive. On the other hand, the negative income elasticities of Wellington was pertained by the increase in car ownership as a result of increase in income.

4.2.5 Fuel Price Elasticity

The estimated fuel price elasticities of bus and rail demand in Auckland, Wellington and Canterbury are depicted in Table 2 and Table 3.

Table 9 Public transport patronage elasticities with respect to fuel price

Trip purpose	Estimated Elasticity
Commuting	0.20
Business	0.24
Education	0.01
Other	0.15
Total	0.13

Source: As cited in Litman (2004) from TRACE (1999).

It is important to note that the fluctuations in fuel price in recent years had been at sustained levels much higher than historical trends which was only comparable to what happened in 1970s. As a result, we would expect that our estimates would be higher than the estimates from international experience.

In the short-run, the fuel price elasticities, for Auckland bus of 0.20 and for Wellington rail of 0.12-0.13, were relatively less elastic than Canterbury, and both comparable with the estimated elasticities for public transport in Europe, as shown in Table 9, of 0.20 for commuting trips and 0.13 for all trips. Bresson et al (2004) also had similar estimates of short-run and long-run fuel price elasticities of 0.08 and 0.14 respectively in France. On the other hand, Canterbury's short-run estimate of 0.28 was higher but comparable with the elasticity of bus patronage with respect to motoring cost in England of 0.32, as shown in Table 4. A higher positive fuel price elasticity represents a higher level of substitution between car and the alternative mode. Our results indicated that the increase in fuel price in recent years had a more substantial effect in Canterbury and Auckland and much less so in Wellington. We believe that this was again due to the fact that Wellington had a much more mature market as compared to Auckland and Canterbury.

5 CONCLUSIONS

In this study, we have achieved the objectives as stated in Section 1. The key factors affecting public transport patronage in the three major cities in NZ were identified; the elasticities with respect to each of the key factors were estimated; and at least one forecast model was developed for each mode in each region.

The following key observations were made:

(1) Service and fare had significant influence in all three cities although not on all modes.
(2) Service had influence in all cities and in almost all modes except Wellington bus.
(3) Rail service and fare elasticites were higher than the corresponding estimates for bus demand in Auckland.
(4) Bus fare was a significant influencing factor in both Wellington and Canterbury but not in Auckland.
(5) Car ownership was an influencing factor for Auckland bus and Wellington rail but fare was not an influencing factor in these cases.
(6) Car ownership elasticities were far higher than the estimates from international experience.
(7) Income elasticities could be negative or positive while international estimates were negative.
(8) The fluctuation in fuel price in recent years had impact in all three cities, although not on all modes. Fuel price elasticity was the lowest in Wellington and highest in Canterbury. The influence of fuel price was found to be significant only in recent years in both Auckland (from 2003Q3) and Canterbury (from 2004Q1) bus demand.
(9) It was evident that the increase in patronage was influenced by the increase in fuel price but not influenced by fare for Auckland bus and Wellington rail.

It is important to note that our methodology and analysis in this study was limited by data availability. There were a few important issues in the data collected. For Auckland, detailed bus information was available only for contract services. They could only represent part of the picture in Auckland. The rail service information was measured in train-kilometres which was not accurate. For Wellington, only annual information for nine years was available. For Canterbury, service information was only estimated from timetables and fare information was only available from 2004. Given these limitations, PAM is the best model that could be applied to all three sets of data available and enabled the comparison between the three regions.

6 ACKNOWLEDGEMENTS

The author would like to thank NZ Transport Agency, NZ Statistics, Auckland Regional Transport Authority, Greater Wellington Regional Council and Environment Canterbury for providing the data and their support throughout this project; Dr Erwann Sbai of the Department of Economics at The University of Auckland, John Davies of Auckland Regional Council, Richard Scott of Booz & Company and Professor Mark Greer of Dowling College for their invaluable advice.

7 REFERENCES

BAH (2006). Impacts of Transport Fuel Price Changes. Booz Allen Hamilton Report for Land Transport New Zealand.

Bresson, G. and Pirotte, A. (1999). Modelling the demand for public transportation (in French). Report VIA GTI-ERMES Université Panthéon-Assas Paris II, December.

Bresson, G., Dargay, J., Madre, J. L., and Pirotte, A. (2003). The main determinants of the demand for public transport: A comparative analysis of England and France using shrinkage estimators. Transportation Research Part A 37, 605-627.

Bresson, G., Dargay, J., Madre, J. L., and Pirotte, A. (2004). Economic and structural determinants of the demand for public transport: An analysis on a panel of French urban areas using shrinkage estimators. Transportation Research Part A 38(4), 269-285.

Dargay, J and Hanly, M. (2002a). The Demand for Local Bus Services in England. Journal of Transport Economics and Policy 36(1), 73-91.

Dargay, J and Hanly, M. (2002b). Bus Patronage in Great Britain – Econometric Analysis. Transportation Research Record 1799, 97-106.

Espino, R, Ortuzar, J de D and Roman, C. (2007). Understanding suburban travel demand: Flexible modelling with revealed and stated choice data. Transportation Research Part A 41, 899-912.

García-Ferrer, A., Bujosa, M., de Juan, A., and Poncela, P. (2006). Demand forecast and elasticities estimation of public transport. Journal of Transport Economics and Policy, 40(1), 45-67.

Greer, M. (2008). Report on the determinants of bus ridership by commuters to work in Auckland. A research report prepared for Auckland Regional Transport Authority by the Energy Centre, the University of Auckland.

Goodwin, P. (1992). A review of new demand elasticities with special reference to short and long run effects of price changes. Journal of Transport Economics and Policy 26(2), 155-163.

Hensher, D. A. (2008). Assessing systematic sources of variation in public transport elasticities: Some comparative warnings. Transportation Research Part A 42, 1031-1042.

Hensher, D. A. and King, J. (1998). Establishing fare elasticity regimes for urban passenger transport: Time-based fares for concession and non-concession markets segmented by trip length. Journal of Transportation and Statistics 1(1), 43-61.

Litman, T. (2004). Transit price elasticities and cross-elasticities. Journal of Public Transportation 7(2), 37-58.

Lutkepohl, H and Kratzig, K. (2004). Applied Time Series Econometrics. Cambridge University Press.

Madre, J.-L. and Boulahbal, M. (1999). Long term forecasting of mobility in relation to urban sprawl and demographic evolution, Presented at UITP Congress, Toronto, May.

Oum, T.H., Waters, W.G., and Yong, J. (1992). Concepts of price eleasticities of transport demand and recent empirical estimates – an interpretative survey. Journal of Transport Economics and Policy 26(2), 139-154.

Pham, L. and Linsalata, J. (1991). Effects of fare changes on bus ridership. American Public Transit Association (www.apta.com).

TRACE. 1999. Elasticity handbook: Elasticities for prototypical contexts. Prepared for the European Commission, Directorate-General for Transport, Contract No. RO-97-SC.2035.

Zeileis, A. (2009). dynlm: Dynamic Linear Regression. R package version 0.2-2. URL http://CRAN.R-project.org/package=dynlm

Appendix The Model Specification

Variable Definitions

After consolidation, each regional data set contains six variables. The definition of the variables considered are summarised in Table 10.

Table 10 Definition of variables

Variable	Definition	Unit
$Q_t^{X\ M}$	Patronage per capita in region X on mode M at time t	Passenger trips per capita per period
$S_t^{X\ M}$	Service kilometres per capita in region X on mode M at time t	Bus-km/train-km per capita per period
$F_t^{X\ M}$	Fare (Real average revenue per passenger) in region X on mode M at time t	New Zealand Dollars (NZD) per passenger
C_t^{X}	Car ownership per capita in region X on mode M at time t	Number of vehicles per capita
I_t	Income (real gross disposable income per capita) at time t	NZD per capita
O_t	Fuel price (real regular petrol price) at time t	cents per litre

where $X = A$ for Auckland; $X = W$ for Wellington; $X = C$ for Canterbury; $M = B$ for Bus; and $M = R$ for Rail.

Model Specification

In this case, our dependent variable is the long-run equilibrium demand for public transport services, or more specifically $Q_t^{X\ M}$, as defined in Table 10.

We assume that the long-run equilibrium demand, in passenger trips per capita, can be expressed as a function f of the service $S_t^{X\ M}$, fare $F_t^{X\ M}$, car ownership C_t^X, per capita disposable income I_t and petrol price O_t.

$$Q_t^{X\ M\ *} = f \ \ S_t^{X\ M}, F_t^{X\ M}, C_t^X, I_t, O_t \tag{1}$$

In estimating the demand model, we assume that all explanatory variables are given or determined exogenously. We further assume a geometrically declining adjustment process, which results in a typical lagged dependent variable model.

$$Q_t^{X\ M\ *} = f \ \ S_t^{X\ M}, F_t^{X\ M}, C_t^X, I_t, O_t \ \ + \theta^{X\ M} Q_{t-1}^{X\ M} \tag{2}$$

where $0 \le \theta^{X\ M} < 1$; and $1 - \theta^{X\ M}$ is the adjustment coefficient which indicates the proportion of the gap between equilibrium and actual patronage that is closed each year.

Assuming that f is in linear form, if all variables are transformed in logarithmic forms, the equation can be expressed as follows:

$$\begin{aligned} \ln Q_t^{X\ M} &= \alpha^{X\ M} + \beta_S^{X\ M} \ln S_t^{X\ M} + \beta_F^{X\ M} \ln F_t^{X\ M} + \beta_C^{X\ M} \ln C_t^X \\ &\quad + \beta_I^{X\ M} \ln I_t + \beta_O^{X\ M} \ln O_t + \theta^{X\ M} \ln Q_{t-1}^{X\ M} \\ &\quad + \gamma_2^{X\ M} D_{2t} + \gamma_3^{X\ M} D_{3t} + \gamma_4^{X\ M} D_{4t} \end{aligned} \tag{3}$$

where $X = A$ for Auckland; $X = C$ for Canterbury; $M = B$ for Bus; and $M = R$ for Rail.

Dummy variables $D_{jt}^{X\ M}$ were created to capture the seasonal effects for the Auckland and Canterbury models, which would not be necessary for Wellington as the model for Wellington was developed based on annual data. That is, the general form of the model for Wellington is as follows:

$$\begin{aligned} \ln Q_t^{X\ M} &= \alpha^{X\ M} + \beta_S^{X\ M} \ln S_t^{X\ M} + \beta_F^{X\ M} \ln F_t^{X\ M} + \beta_C^{X\ M} \ln C_t^X \\ &\quad + \beta_I^{X\ M} \ln I_t + \beta_O^{X\ M} \ln O_t + \theta^{X\ M} \ln Q_{t-1}^{X\ M} \end{aligned} \tag{4}$$

where $X = W$ for Wellington; $M = B$ for Bus; and $M = R$ for Rail.

With this model, as represented by equations (3) and (4), we can estimate both the short-run and long-run elasticities at the same time; the short-run elasticities as the coefficients of the independent variables and the long-run elasticities as the short-run elasticities divided by the adjustment coefficient $1 - \theta^{X\ M}$.