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Forecasting annual train boardings in Melbourne using time series data

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Abstract

This paper analyses the relationship between yearly train boardings in the Melbourne metropolitan area and six theoretically explanatory economic and demographic variables over the period twenty seven year period 1983-84 to 2009-10. Two of these variables were lagged by three months, and by six months. A series of univariate linear regression analyses was performed, followed by several multivariate regression analyses of various combinations of the independent variables which showed the highest explanatory power. The three independent variables with the highest explanatory power are in descending order the annual average percentage of total interest payments to household income(lagged 3 months), the estimated resident population in the Melbourne Statistical Division (X_6), and the estimated number of persons employed (both full and part time) in the Melbourne Statistical Division. Multivariate regression analyses yield several usable forecasting equations. The one of which is the basis of the presented forecast of train patronage from 2010-11 to 2012-13 comprises three explanatory variables: the real average annual price of a zone 1 ticket, the real average annual price of unleaded petrol (lagged 3 months) and the estimated resident population of Melbourne. Time series forecast are also presented. Both types of forecasts indicate an increase in train patronage from 2010-11 to 2012-13 that is double the average annual rate of growth experienced in the previous three years. Limitations of this research and future research plans are outlined.

1. Introduction

This paper presents the results of a time series quantitative analysis of the extent of the relationship between a range of independent variables and the reported level of patronage of a key element of the public transport system in Melbourne, Victoria, Australia; namely the city's train system.

The primary aims of the research reported here are:

1. to investigate the degree of statistical association between the historical levels of demand (as measured by millions of boardings per year) for train services in Melbourne and a range of independent variables, with emphasis on those proven by earlier researchers to be influential in demand for public transport;
2. to identify the set of independent variables that are most closely correlated with the annual movements in train boardings in Melbourne over the period 1983-84 to 2009-2010;
3. to use the resultant regression equations to derive forecasts of train boardings in Melbourne over the next three years ending June 2013; and
4. 4. to compare the forecasts arising from aims 3 and 4 with the official government forecasts of public transport demand over the near-medium term.

The rest of the paper provides:

- a brief background on Melbourne and its public transport system;
- a review of previous quantitative time series studies into public transport demand influencing factors and variables;
- the data set and empirical methodology used in this research;
- the key results and findings of the regression analyses;
- forecasts of patronage of Melbourne's trains over the four years ending June 2013;
- a comparison with official government forecasts; and
- overall conclusions, research limitations and plans for future research.

2. Brief background of Melbourne and its public transport system

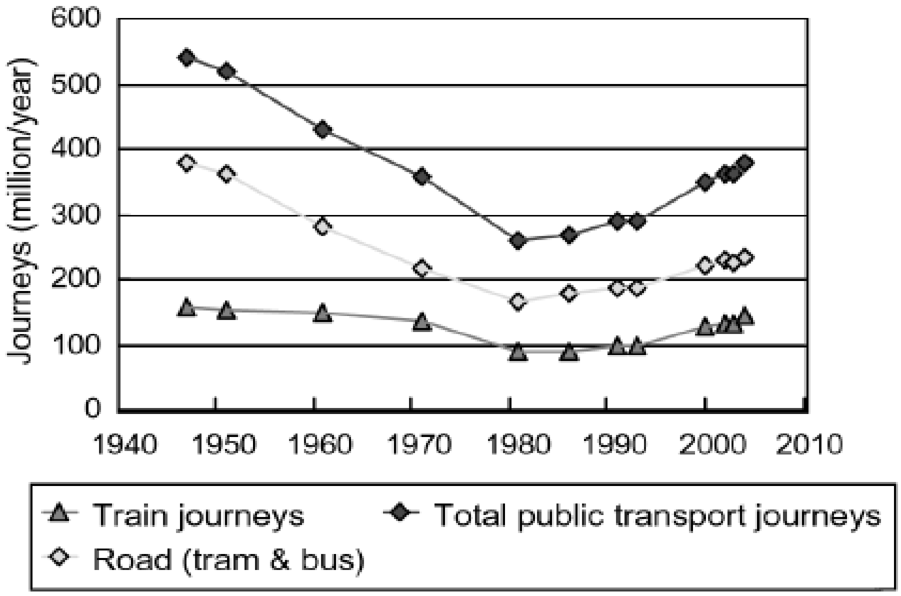
The Melbourne Statistical Division (MSD) had an estimated population of 4.08 million at June 2010, 'an increase of 79,000 people or 2.0% since June 2009' (Australian Bureau of Statistics [ABS] 2011). Melbourne has been the fastest growing capital city in Australia over the nine years ending June 2010 (ABS 2011). This population growth however has not been evenly spread, with the largest and fastest growth occurring in its outer fringe areas.: in 2010 'Wyndham, located to the south-west of Melbourne's city centre, had the largest growth of Victorian LGAs, increasing by 12,600' (ABS 2011).The inner city of Melbourne itself however did achieve above average growth in 2009-2010: ' Melbourne had the eighth largest increase in population of all LGAs in Victoria in 2009-10 (up 3,400 people) and continued to experience relatively fast growth at a rate of 3.6%. A forecast prepared in late 2002 predicted Melbourne's population to reach 4.5 million people by the year 2031 (Eddington 2008). Subsequently however this population figure has been predicted to be reached in 2020 (Birrell and Healy 2008).

Melbourne is served by three modes of public transport: rail, tram, and bus. Both the train network and the tram network operate in a radial manner, with all train spokes emanating from the CBD. Melbourne's metropolitan train system comprises fifteen distinct routes network radiating from central Melbourne and consists of a total of 382 network route kilometres, (Department of Transport 2008a) offering more than 1930 daily services (Department of Transport 2009a). The tram network 'radiates from central Melbourne on 29 routes and consists of 249 kilometres of double track' (Department of Transport 2008a). The bus network comprises an 'extensive network bus services operated on behalf of the State by private companies, totalling 309 routes and approximately 1500 buses' (Department of Transport 2008a).

Melbourne's metropolitan public transport system operates as a multi-zonally one. The zonal pricing regime started in October 1981 with the creation of three travel zones and the introduction of the first tickets to offer unlimited all day travel on all metropolitan transport services across the greater Melbourne area. In March 2007, the State Government eliminated Zone 3 in an effort to reduce the cost of public transport in outer suburban areas (Minister for Public Transport 2007a). A new ticketing system, *myki* was announced in 2007 to replace the Met card system. Suffice to note in this brief overview that its introduction has been fraught with on-going difficulties — both technical and financial — and to date the newly elected government has yet to signify if it will honour the legal contracts entered into by its predecessor or ditch myki altogether .

Figure 1 presents the annual patronage figures for Melbourne's three public transport modes and the total patronage over the years 1946-7 to 2004-05 (Cox, 2007). As shown public transport usage over the years 1946-7 to 2004-05 has been in two distinct phases. The first is a long period of decline up to the early nineteen eighties. The population of Melbourne at the census date in 1947 was slightly above 1.2 million (ABS, 1947; 2011). On a per capita basis, Figure 1 suggests that in the late nineteen forties each Melbournian took around 125 train trips per year. By 1981 this per capita annual number of train tips had fallen to around 33 based on a resident population if some 2.8 million (ABS) annual train boardings of around 96 million. Probably the main reason for this substantial and potentially irreversible decline in per capita modal share is the launch in 1948 followed by the rapid diffusion of the locally manufactured and affordable Holden motor vehicle. The second phase of public transport patronage in Melbourne evidenced in figure 1 is an uneven but distinct rebound phase that began in the early 1980s. Phase 2 shows resurgence in public transport usage, about which more will be noted shortly.

Figure 1: Long-term patronage trends



Source: Cox (2007)

This restructuring and franchising process of Victoria's train and tram services began in earnest in October 1998, when expressions of interest were invited, and culminated in the selection of successful bidders for the five passenger rail businesses in June/July 1999. Three of the five franchises were awarded to UK transport operator National Express. In December 2002, however, National Express withdrew from operating in Victoria; consequently the Victorian State Government temporarily resumed responsibility for 'operating the M>Train, M>Tram and V/Line passenger businesses (Department of Transport 2008a). In 2004 the State Government entered into new partnership agreements for the operation of Melbourne's tram and train services with Connex. Under the 2004 franchise agreements, the state assumed responsibility for some of the on-going costs of operating the metropolitan train and tram system (Department of Transport 2009a). The most recent tender agreements were finalised in September 2009, with both the incumbent franchisees being replaced by new private sector operators, MTM (operating as Metro) and KDR (operating as Yarra Trams) were awarded contracts to operate the Melbourne metropolitan train and tram networks for eight years, with an option for a seven-year extension (Department of Transport 2010a). The new franchisees commenced operations in December 2009 (Department of Transport 2010b**)**. Metro replaced Connex as Melbourne's train system operator.

3. Review of previous quantitative studies of variables associated with transit demand

The purpose of this section is to outline the findings of earlier quantitative studies that are most relevant to this study's aims. Conventionally a distinction is made between internal (or direct) and external (or indirect) variables. The internal variables are those that can be set or controlled by the transit system's senior decision makers; and include such parameters as fares and service levels (Taylor and Fink c. 2003). Conversely external variables are those over which the relevant transit authority has no direct influence or control. Such external variables can be separated into two distinct types: macro-level variables and individual level variables. Table 1 summarises the most frequently used of these distinct types of independent variables, and provides examples of specific operationalisations of these variable types.

A brief review of some relevant research and in particular the resultant quantitative findings for each of the variables specified in Table 1 are is now provided. A discussion of the main results and findings of earlier quantitative research on the impact of internal factors on public transport demand is presented first.

The internal variable most frequently investigated is the price or fare charged by public transport agencies. Most Most of the studies reviewed present findings in respect of the value of price elasticity of demand, rather than advancing conclusions about the degree of correlation between public transport fares and public transport demand. Overall, the literature reviewed shows that the influence of public transport fares and changes thereto on public transport patronage levels is quite variable, both in a geographic and a quantitative sense.

Taylor et al (2002) question the universal applicability of the negative relationship between the price of public transport and the demand for it, by noting that while patronage increased strongly when fares decreased, 'increasing average fares appeared to have little (or even a slightly positive) relationship with ridership'; more specifically between 1994 and 1999 'agencies with little change in the average fare, as a group, saw ridership climb 8.5 per cent, while agencies that increased average inflation-adjusted fares by more than 5 per cent, as a group, increased ridership by 10.3 per cent' (Taylor et al 2002). Kohn (2000) examining data from 1992 to 1998 in a study of 85 Canadian urban transit agencies reached a similar conclusion to Neuzil (1975) in that, taken together, average fare and revenue vehicle hours explained 97% of changes in urban transport demand. Albalate and Bel (2009) in a cross sectional regression analysis of both public transport supply influencing and demand influencing factors across 45 European cities find that the average price of public transport has statistically significant but negative impacts on public transport demand.

Table 1: Frequently used internal and external independent variables

Internal variables	Macro-level External variables
Fare/ price per journey	Petrol prices: average retail price unleaded petrol; real gasoline prices
Service quality: service information availability; customer and on street service; in journey comfort	Car ownership; access to private motorised transport.
Service reliability: passenger waiting time; access and egress times; service punctuality; in vehicle time	Parking: availability of parking; price of parking
Service capacity: per capita transit capacity; size of transit fleet, number of routes	Employment: Total employment in region; CBD employment
Service frequency: vehicle miles / kilometre hours	General economic conditions: variations in real GDP; regional Gross Value Added per head

Internal variables	**Macro-level External variables**
Average speed of public transport vehicles; relative speed of public transport vis a vis vis-a-vis private transport	Income: real household income; average annual income; disposable income.
Individual level external variables	Population: metropolitan area population; regional population
Traveller attitudes and habits	Urban density: housing density per acre; employment density
Traveller perceptions	Government support: availability and appropriation of finance to public transport.

The second internal variable noted in Table 1 is the quality of service provided to users of public transport. Increasing the quantity of service (in terms of service coverage and service frequency) is 'found to have significant effects on ridership' (Taylor et al 2002). However, Neuzil (1975), who studied the determinants of transit ridership in small areas using time series data collected over several years and for different decades cautions against indiscriminately applying the 'service factor/ ridership relationships' found in his study 'to any particular urban area' without making 'adjustments for local conditions-community factors and transit system parameters' and without undertaking 'consistency checks with other patronage estimation criteria.' Tegner et al (nd) using a two stage aggregate non-linear time-series demand share model found that service elasticity is 0.29 for monthly public transport cards in Stockholm. Service factors are more important in attracting passengers than changes in fares or quantity of services: a 'compelling argument can be made for operating more premium quality transit services at higher prices' (Cervero 1990).

The third internal variable identified in Table 1 focuses on the impact of service reliability on public transport demand. Balcombe et al (2004) note that the many and varied attributes of public transport vehicles render the direct quantitative analysis of their specific effects on demand very hard. However research based on stated preference techniques has yielded some insights; for instance:

- rolling stock improvements can moderately effect affect demand and are 'typically valued at around 1 -2% of in-vehicle time (Balcombe et al 2004);
- in vehicle improvements such as changes in seating layout, ventilation and the like would generally be worth around 1.5% of the fare (Balcombe et al 2004);
- overcrowding can have a significant negative effect on demand (Balcombe et al 2004).

The fourth internal variable specified in Table 1 focuses on service capacity. Sale (1976) as cited in Taylor et al (2002) finds that most increases in public transport ridership in the United States are largely attributable to service expansion — especially route expansion in rapidly growing metropolitan areas. However Taylor, Miller et al (2003) find that 'ridership gains are not simply the direct result of added service (frequency and coverage)'.

This review now turns to the extant empirical research on the influence of external factors on public transport demand. Such variables are those that are largely beyond the direct control of the public transport system and its managers: they and include individual level variables, and macro-level parameters. as employment levels and employment density, service area population, private vehicle access and/ or ownership, income levels, price of gasoline, and the cost of vehicle parking'.

Quantitative research on the influence of individual travelers' attitudes and perceptions on the use of public transport specifically, and the alternative transport modes generally, have a long and rich history: for a good review see Diana (2010). Kuppam, Pendyala and Rahman (1999) (as cited in Parkany, Gallagher and Viveiros 2004) note that while both demographic and attitudinal variables are both 'extremely important in explaining mode-choice behavior', attitudinal factors 'were found to contribute more' to consumer mode choice than demographic factors.' Gilbert and Foerster (1997) conclude that 'attitudinal data, including both attitude items and measures of perceptions of system attributes, do enhance the predictive power of models involving network data**.'** However, social psychology meta-analyses suggest that the correlation between attitude and behavior is very low (Parkany, Gallagher and Viveiros 2004). For instance, Fujii and Garling (2003) in a study of the relationship between attitude and behaviour to a new Kyoto, Japan, subway system among public transport customers found a correlation of 0.505 (as cited in Parkany, Gallagher and Viveiros 2004).

Gardner (2009) investigates the role of habit in influencing or potentially pre-determining behaviour. In his first study on the relationship (2009), Gardner found that The first study by Gardner (2009) involved university staff and student university-based car commuters with access to a car over the preceding week (Gardner 2009). One result Gardner (2009) reports is that 'intention, habit and behaviour were significantly positively correlated ($ps < .001$). bBehaviour correlated strongly with past behaviour ($r = .86$, $p < .001$), demonstrating the stability of commuting mode choice: and that' Second, Gardner (2009) reports that 'intention had a stronger effect on behaviour ($\beta = .60$, $p < .001$) where habit was weak, but where habit was strong there was no relationship between intention and behaviour ($\beta = -.04$, $p = .82$).

The research findings on the relationship between petrol prices and public transport demand are varied. McLeod et al (1991) in a multivariate time series regression study of public transport did not find fuel prices to be a significant demand influencing factor. Conversely, Sale (1976) in a study of seven transit systems with annual ridership growth of at least 5% per annum found that significant increases in fuel prices had an immediate and positive affect on transit ridership Liu (1993) found that a 1% annual increase in real gasoline prices is associated with a 0.274% annual increase in linked transit trips. In Melbourne, Australia, petrol prices have been found to be directly associated with the level of public transport patronage: 'should petrol prices increase, train patronage forecasts suggest growth will continue at 3.5 per cent per annum in the short to midterm' (Department of Transport 2008a). Currie and Phung (2006) find that cross elasticities between petrol price and public transport demand in general are highest with a 7 month time lag for rail commuters. Odgers (2009) finds that the average price per litre of unleaded petrol is the single most explanatory variable of those analyzed in respect of annual train patronage over the period 1983-4 to 2007-8 in Melbourne, Australia, with an adjusted R^2 of 0.902.

Another set of variables that some earlier researchers have identified as being correlated with public transport demand centre of vehicle ownership and vehicle usage. Taylor and Fink (c.2003) state that collectively 'variables which directly or indirectly measure automobile access and utility (including auto ownership and parking availability) explain more of the variation in transit ridership than any other family of factors'. Cameron, Lyons and Kenworthy (2004) concur, noting that increased vehicle ownership, combined with population growth, have been the 'driving forces' behind much of the observed increases in vehicle kilometres travelled (vkt)' in the seven international cities they studied. Balcombe et al (ed.) (2004) observe that in the U.K. increased car ownership — and in particular a first car acquired by an individual —'has had a direct effect (and negative) on public transport use.' Conversely Albalate and Bel (2009), in their previously cited study, based on a cross sectional regression analysis of both public transport supply influencing and demand influencing factors across 45 European cities find that motorization in the metropolitan area does not seem to explain public transport demand.

The availability of car parking and its cost have also been found to be significant 'drivers' of public transport patronage. Morral and Bolger (1996) for example found that the number of downtown parking stalls per CBD employee explained 92 per cent of the variation in per cent transit modal split for Canadian cities and 59 per cent for Canadian and American cities combined. Chung (1997) also finds that parking is the most significant factor affecting transit ridership. Albalate and Bel (2009), in their previously cited study, in a cross sectional regression analysis of both public transport supply influencing and demand influencing factors across 45 European cities find that the number of parking spaces in the central business district has a statistically significant but negative impact on public transport demand. In Australia the Department of Transport Victoria (2008a) believes that the increased cost of long-term, parking in Melbourne's Central Business DistrictCBD has had an influence in the recent increase in public transport patronage levels.

The influence of employment levels and conditions on public transport demand has also been researched**.** Hendrickson (1986) as cited in Taylor et al (2002) in a cross sectional study of 25 large U.S. cities explores the relationship between four variables — the percentage of workforce in CBD, the absolute number of workers in CBD, absolute number of work transit trips, and percentage of work trips taken on transit. Hendrickson (1986) finds that the 'model explains 96 per cent of the variation of public transit use, signalling a strong relationship between transit use and CBD employment', as cited in Taylor et al (2002). Na (2007) reports on a time series study of train demand in London over the years 1995 to 2002. Of the variables investigated, central London employment is the most important factor that affects transport demand (Na, 2007). In Australia, the The Department of Transport (2008a) notes its belief that increased employment growth in Melbourne's CBD has positively influenced public transport patronage levels. Balcombe et al (2004) also notes that in the U.K. demand rail travel 'appears to be strongly correlated with employment.'

The demand for public transport is arguably influenced by the state of the economy. Taylor et al (2002) find that overall transit ridership levels track closely with both real GDP (R^2 = 0.. 79) and with measures real GDP per capita (R^2 = 0. 0.82). Conversely, Beko (2003) finds that the addition of real GDP to a time series regression analysis of public transport demand in Slovenia did not strengthen the explanatory power of the model. Albalate and Bel (2009), in their previously cited study, based on a cross sectional regression analysis of both public transport supply influencing and demand influencing factors across 45 European cities conclude that GDP is positively correlated with passenger-km per capita.

The level of income — at an individual and a group or regional level — will arguably influence public transport demand. Once more however the results from earlier studies convey mixed messages. Taylor et al (2002) state that the 'correlation between average real wages and total transit ridership during the 1990s was almost perfect (0.96)'. Conversely Bresson et al (2003) find that for England public transport is 'clearly an inferior good' with a long-run elasticity around -0.9; across the English Channel however income 'appears to have had little effect in France during the period 1987-1995' (Bresson et al 2003). In Australia, the Victorian Department of Transport (2008a) believes that the tightening of household budgets that has resulted from 'increased mortgage repayment's is one of a range of factors that has influenced public transport patronage levels in the years 2005-6 to 2006-7'. The percentage of household income allocated to the payment of housing interest is shown to have a direct and positive impact (adjusted R^2 0.892) on annual train patronage levels in Melbourne over the years 1983-4 to 2007-08 (Odgers 2009).

Population and population dynamics have also been shown to be influential in affecting public transport demand**.** Taylor, Miller, Iseki and Fink (2003) for instance find that 'most of the variation in transit ridership between urbanized areas– in both absolute and relative terms–can be explained by (1) the size (both population and area) of the metropolitan area, (2) the vitality of the regional economy (measured in terms of median housing costs), and (3) the share of the population with low levels of private vehicle access (measured in terms of zero-vehicle households).' The Victorian Department of Transport (2008a) states its belief that increased population growth over the decade ending 2007 has had a positive influence in growing public transport demand. Hendrickson (1986) finds that changes in regional population are less important than changes in CBD employment.

The final external variable specified in Table 1 centres on the extent and longevity of government support for public transport. Individual demand for various transport modes is influenced by governmental policies that can either favour, or discourage the specific modes of transport: see for example the Singapore government's use of various fiscal strategies to discourage demand for automobile ownership (Cameron, Lyons and Kenworthy 2004). Munich is another medium-sized city that has clearly influenced inter-modal demand through such measures a pedestrian only streets in its city centre and a strong commitment to 'an efficient and viable public transport network' (Cameron, Lyons and Kenworthy 2004). Sale (1976) found that the availability of substantial and secure government provided financial resources was one of three most important factors having a significant effect on transit share mode in the short-term. Taylor et al (2002) find that one of the key factors driving the large increase in transit ridership experienced across the United States between 1994 and 1999 was 'heavy public spending on transit.'

In very brief summary, a range of variables both internal and external have been found by earlier researchers to have a direct statistical relationship with and potentially influence over the level of demand for public transport, both at a point in time and over time. No one variable however has been identified as being universally a strong explainer of public transport demand. Nor has the theoretical negative relationship between price and quantity demanded always been found to apply.

4. Variables, model and methodology

The dependent variable investigated in this study is the annual passenger boardings (millions) per year on Melbourne's trains. Table 2 presents these data for the twenty seven years ending June 2010.

Table 2: Train boardings per year Melbourne 1983-4 to 2009-10

Year	Train boardings (millions)	Year	Train boardings (millions)
1983-84	92	1997-98	113.5
1984-85	99	1998-99	118.1
1985-86	100	1999-2000	124.2
1986-87	112.7	2000-01	130.3
1987-88	101	2001-02	131.8
1988-99	107	2002-03	133.8
1989-90	108	2003-04	134.9
1990-91	108.5	2004-05	145.1
1991-92	109.5	2005-06	159.1
1992-93	105.9	2006-07	178.6
1993-94	101.1	2007-08	201.2
1994-95	105.5	2008-09	213.9
1995-96	109.2	2009-10	219.3
1996-97	112.5		

Sources: 1984/5 to 1987/8 Australian Bureau of Statistics (1990); 1988-89 to 1991/92 Public Transport Division (2008); 1992-93 to 1996-97 Auditor-General Victoria (1998); 1998-99 to 2006-7 Department of Infrastructure (2007); 2007-8 from Press release Office of the Premier August 20 2008; 2008-9 patronage data from Department of Transport (2009d); 2009-10 patronage data from Department of Transport (2010b).

Collecting the data for the yearly value of passenger boardings for trains specified in Table 2 was marked at times by concerns about data validity and data consistency over time. and was not as straight forward as one might be entitled to expect. One concern is that the annual patronage data published by the responsible government department are estimates rather than actual passenger boardings. The Victorian Department of Infrastructure (2007) noted that a new measurement methodology was introduced from 2004-05, and it resulted in several changes to previously published patronage data. Moreover a single authoritative data source on train patronage in Melbourne covering the last three decades does not exist. Several separate and at times conflicting data are presented by public authorities. A third reason for caution is that from 29 August 1999 the operation of Melbourne's public transport has been in the hands of private operators (Department of Transport 2008a). An unfortunate consequence for researchers has been the loss of direct access to comprehensive public transport historical data sets, especially for time periods earlier than 1995. The earlier research that has been summarised in section 3 has guided the selection of independent variables for this current study that are itemised in Table 3. The other key criterion used to select external variables for this study is the public availability of reliable annual data for each variable over the years 1983-4 to 2009-10 inclusive. Some potential variables were excluded on this basis.

Table 3: Independent variables used

Variable	Variable number	Expected sign of coefficient	Primary data source(s)
Real average annual price of a full-fare Zone 1 weekly ticket	X_1	$\beta_1 < 0$	Minister for Public Transport (Various); Australian Bureau of Statistics (2011a)
Real average annual price/ litre of unleaded petrol, Melbourne	X_2	$\beta_2 > 0$	Australian Bureau of Statistics (2008-2010); Australian Bureau of Statistics (2011a)
Real average annual price per litre of unleaded petrol lagged 3 months	X_{2a}	$\beta_{2a} > 0$	Australian Bureau of Statistics (2008-2010); Australian Bureau of Statistics (2011a)
Real average annual price per litre of unleaded petrol lagged 6 months	X_{2b}	$\beta_{2b} > 0$	Australian Bureau of Statistics (2008-2010); Australian Bureau of Statistics (2011a)
Estimated number of persons employed (both full and part time) in the Melbourne Statistical Division	X_3	$\beta_3 > 0$	Australian Bureau of Statistics (2009a, 2010)
Total weekly earnings persons (Victoria)	X_4	$\beta_4 > 0$	Australian Bureau of Statistics (2008a-2010)
Average annual housing interest paid as a percentage of household disposable income	X_5	$\beta_5 > 0$	Reserve Bank of Australia (2010)
Average annual housing interest paid as a percentage of household disposable income lagged 3 months	X_{5a}	$\beta_{5a} > 0$	Reserve Bank of Australia (2010)
Average annual housing interest paid as a percentage of household disposable income lagged 6 months	X_{5b}	$\beta_{5b} > 0$	Reserve Bank of Australia (2010)
Estimated resident population in the Melbourne Statistical Division	X_6	$\beta_6 > 0$	Australian Bureau of Statistics (2009b, 2010, 2011b)

It needs to be noted that the accuracy of the value of the average zone 1 full fare used in this analysis prior to 1997-98 cannot be fully ensured since the responsible government department was unable to provide the current researcher with any fare data prior to the late nineteen nineties. A range of other sources were consulted and the consistency overall of the percentage average annual price rise being closely aligned to the increase in average weekly earnings was used to infer the average annual zone 1 full fare price in those earlier years.

Table 3 also specifies the expected sign of the coefficient for each variable, based on micro-economic theory, and the primary data sources used to assemble the data set. The variables are the same as those used in Odgers (2009), except for variable X_1 which is now the real price of a full-fare Zone 1 weekly ticket, and variable X_2 which is now the real price per litre of unleaded petrol in Melbourne. The base year (index = 100) for the deflation of the current values of both these variables is 1983-84 and current prices per year were adjusted on the basis of the Australian Bureau of Statistics (2011a) Melbourne (Consumer Price) Index Numbers All Groups average yearly index value expressed as an index number relative to the 1983-4 average value. The real value of the both the price of a zone 1 full fare ticket (variable X_1) and the average price per litre of unleaded petrol in Melbourne (variable X_2) have been used based on the feedback of reviewers of any earlier version of this paper in order to remove the statistical impact of inflation-induced price rises on the relationship between this explanatory variable and the dependent variable, annual train boardings. The second difference to Odgers (2009) is that the values for variables X_5 to X_{5b} for the years 19083-4 to 2007-8 are different. The reason for the differences in values is that as of January 2010 the Reserve Bank of Australia has changed the method used to quantify the value of both ‘Interest payments to disposable income – total’ and ‘Interest payments to disposable income – housing’ from the previous way of using unpublished ABS data, which have been discontinued’ to the new method wherein the Reserve Bank uses ‘average interest rates on outstanding housing and other personal debt.’

The resultant data sets were analysed using Ordinary Least Squares linear regression analysis. Univariate linear regression analysis was performed using each of the ten independent variables specified in Table 3, over the years 1983-84 to 2009-10. The resultant equations were examined especially in respect of the R^2, adjusted R^2, Standard Error of Estimate (SEE), and t value. The second analytical method used was a multivariate forward regression analysis. All calculations were performed at the 5% level of significance**.**

5. Results and findings

Table 4 presents selected characteristics of the univariate OLS regression analysis for the independent variables studied. The first characteristic selected is adjusted R^2. This is chosen over the more frequently reported R^2 since sample R^2 ‘tends to be an optimistic estimate of how well the model fits the population’ (SPSS Manual v. 11). The adjusted R^2 for each of the independent variables in Table 4 apart from variables X_1 and X_2 to X_{2b} indicates a medium to high level of statistical association the dependent variable and these explanatory variables. The three independent variables with the highest explanatory power based on the R^2 value are in descending order the annual average percentage of total interest payments to household income (X_{5a} ,X_{5b} ,X_5), the eestimated resident population in the Melbourne Statistical Division (X_6), and the estimated number of persons employed (both full and part time) in the Melbourne Statistical Division (X_3).

The Standard Error of Estimates (SEE) in Table 4 range from 13.91 for variables X_{5a} to 24.546 for variable X_2. In relation to the average value of the dependent variable, annual train boardings, these SEE equal standard errors of estimate of 10.8% to 18.8% of that mean value. Other things being equal the variable with the lowest SEE is statistically preferred for predictive purposes over other variables with higher standard errors of estimate. Use of this convention indicates that variable X_{5a} offers the lowest standard error of estimate. The t values presented in Table 4 of each of the ten independent variables are statistically significant when compared with the critical t value for 25 degrees of freedom at the five per cent level of significance of 2.06.

Table 4: Univariate regression results 1983-4 to 2009-10

Variable	Adjusted R^2	SEE	t value	Unstandardised Coefficient		Standardised coefficients
				Beta	Standard error	Beta
X_{1r}	0.539	24.209	5.606	20.244	3.611	0.746
X_2	0.526	24.5461	5.468	490.122	89.642	0.738
X_{2a}	0.586	22.9537	6.146	521.788	84.898	0.776
X_{2b}	0.576	23.221	6.028	508.646	84.379	0.770
X_3	0.830	14.725	11.293	0.137	0.012	0.914
X_4	0.789	16.371	9.920	0.181	0.018	0.893
X_5	0.836	14.428	11.570	17.279	1.493	0.918
X_{5a}	0.848	13.910	12.080	17.681	1.464	0.924
X_{5b}	0.845	14.043	11.947	17.651	1.477	0.922
X_6	0.831	14.647	11.365	0.099	0.009	0.915

Apart from independent variable 1 (the average price of an adult full-fare zone 1 ticket), the sign of each of the unstandardised coefficients complies with the proposed sign (see Table 3). Our comments will return to this anomaly immediately below. However as they reflect each independent variable in its original unit of measurement they cannot be directly compared with each other. The final statistic presented for each independent variable in Table 4 — the standardised coefficients (beta weight) — partly overcomes this problem since it is 'based on z scores with a mean of 0 and a standard deviation of 1' (Meyers, Gamst and Guarino 2006).

As just noted, the most theoretically surprising result of this study is the unexpected nature of the relationship between price, as represented by real average annual weekly zone 1 full fare (X_1) and train patronage. Table 4 shows the unstandardised beta coefficient of X_1 at 20.244. The positive sign of this coefficient is clearly not in keeping with standard microeconomic theory. However it does confirm the findings of Taylor et al (2002) noted earlier in this paper. One possible explanation for both the counter-theoretical direction of the association between price and quantity demanded in the current study is that the price of a full weekly ticket in Melbourne has averaged 2.95% of weekly earnings, with a standard deviation of 0.3%, over the years 1989-90 to 2009-2010. Public transport fares then have been a consistently relatively low percentage of average weekly earnings, and the cost of travelling on public transport relative to the cost of travelling via a motor vehicle as a percentage of disposable income has decreased over the last several years with quickly rising petrol and other vehicle operating costs.

Another of the surprising findings of this analysis is that the strength of correlation between the real average annual price per litre of unleaded petrol (X_2) and train patronage in Melbourne during the period 1983-84 to 2008-09 is lower than any of the selected explanatory variables with the exception of the price of a zone 1 full fare (X_1). Univariate regression analysis was done (but not reported here) using the current price of unleaded petrol in Melbourne: this analysis lead to an adjusted R^2 for X_2 train boardings of 0.879. Theoretically this result is not unexpected as driving a vehicle is a close substitute to commuting on public transport The strength of the positive association between petrol prices in Melbourne and train patronage is not unexpected, especially when it is noted that 'over the 10 year period between 1998 and 2008, the percentage of the weekly wage needed to purchase the same amount of fuel increased from 6 per cent to a peak of 9 per cent in 2008 (VicRoads 2008/09 p. 5)'. This quantitative result on the direct association between fuel price increases and higher transit demand supports the findings of Sale (1976), but contradicts the results reported by McLeod et al (1991). Clearly the use of a rail price value for this variable has a quite major impact of its explanatory value, since the adjusted R_2 for variable X_2 is 0.526, as opposed to the value of 0.879 noted above. Also noteworthy is the slight increase in explanatory power of the variable X_2 the real average annual price per litre of unleaded petrol when it is lagged either by 3 months (adjusted R^2 = 0.586); or by 6 months (adjusted R^2 = 0.576).

The positive and reasonably high degree of correlation of the independent variables X_3 (persons employed) and X_4 (total weekly earnings) on changes in train patronage shown in Table 4 are consistent both with economic theory and the results of earlier researchers, especially Na (2007) and Balcombe et al (2004). The positive link between population growth and demand for trains is evident in Table 4: independent variable X_6 has an adjusted R^2 of 0.831. Such a positive and high correlation is consistent with both economic theory and the results achieved by earlier researchers, such as Taylor, Miller, Iseki and Fink (2003).

The other key finding of the univariate analysis is the strength of the correlation between the dependent variable and fifth explanatory variable, the annual average percentage of housing interest paid to household disposable income (X_5). As shown in Table 4 the adjusted R^2 of variable X_5 (0. 836) is the second highest of the six non-lagged independent variables tested. It is interesting to note that the adjusted R^2 is higher than that for both variable X_3 (persons employed) of 0.830 and variable X_6 (resident population).

Multivariate regression analysis was then performed to investigate the extent of the change in predictive power that resulted from combining two or more of the independent variables into a multiple linear regression function. Forty five sample multiple linear regression functions were produced and examined. Twenty four of these were rejected because one or more of the independent variables t-value(s) failed the critical value significance test (at the 5% significance level), or because the extent of multicollinearity exceeded acceptable levels (more will be noted on this point shortly). Table 5 provides a summary of the five multiple regression functions multiple regression functions that produced the statistically strongest results in respect of adjusted R^2, standard error of estimate (SEE) , Durbin-Watson computed value, and Variance Inflation Factor (VIF).

Each of the sample regression functions shown in Table 5 yield adjusted R^2 of more than 0.9. Each function presented in Table 5 also generates a reasonably low proportional value of Standard Error of Estimate (SEE) relative to the actual average annual patronage levels for train boardings over the twenty seven years studied of 128.7 million: the lowest is 6.7% (using variables X_1, X_2 and X_6) and the highest is 8.2% (for variables X_{2a} and X_3) . The value of the t statistics for each of the explanatory variables is greater than the critical value, indicating that there exists a significant linear statistical relationship between the dependent and each of these independent variables. The functions involving (i) variables X_{2a} and X_3 return a computed Durbin-Watson value of less than the D-Wdl value of 1.06 indicating that there is no autocorrelation present in the residuals. The computed values for the other four sample regression functions presented in Table 5 lie between D-Wdl and D-Wdu indicating that the Durbin-Watson test for autocorrelation is inconclusive.

The challenge of the frequent incidence of multicollinearity in multiple regression functions has been assessed. Firstly the Variance Inflation Factor (VIF) has been computed and compared to the recommendation that a VIF score of 10 or more indicates a serious extent of multicollinearity (Meyers, Gamst and Guarino, 2006**).** As shown in Table 5 the VIF for each of independent variables in the sample regression functions with the highest adjusted R^2 of 0.955 range from 5.045 (for variable X_6) to 1.558 (for variables X_{2a}). The VIF for each variable in the last two equations presented in table 5 are all less than 2.0. In each of the five equations there is no single variable with a VIF value of more than 10, the score of 10 being flagged by Meyers, Gamst and Guarino (2006) as evidencing strong and unacceptable levels of multicollinearity. We also concur with the remarks of Flaherty et al (1999, p. 393) that where a suitable theoretical model has been developed 'removing variables, simply because they may lack certain desirable statistical properties, should not be seen as an automatic solution'. We also acknowledge Makridakis and Wheelwright (1978, p. 210) who note that 'as long as all t-tests are significant — even though some independent variables are highly correlated — there is no serious multicollinearity.'

Table 5: Multivariate analysis results for 'best' sample regression functions (1983-4 to 2009-10)

Variable(s)	Adj R^2	SEE	t Statistics	DW	VIF
X_1, X_{2a}, X_6	0.955	7.56	-4.81 7.575 11.258	1.118	4.974 1.558 5.045
X_1, X_{2b}, X_6	0.954	7.668	4.693 7.424 11.389	1.384	4.964 5.042 1.563
X_1, X_2, X_6	0.941	8.667	-4.265 6.717 10.469	1.091	5.016 1.535 4.973
X_{2b}, X_3	0.918	10.193	5.308 10.283	1.207	1.496 1.496
X_{2a}, X_3	0.917	10.258	5.246 10.059	0.97	1.524 1.524

Notes

1. Critical t values (two tailed area α =0.05) for df =23 is 2.07; for df = 24 is 2.06.

3. For 3 variable and 27 observations D-Wd_l = 1.06 and D-Wd_u = 1.54; for four variables D-Wd_l = .99 and D-Wd_u = 1.64.

4, VIF is Variance Inflation Factor

6. Forecasts of train patronage based on regression analysis

The forecasts of train patronage (T) for the years 2010-11 to 2012-13 presented in this section are based on the following sample regression equation (1) drawn from the results of multivariate analysis outlined immediately above (all cases a =0.05).

$$T = -258.59 - 12.095X_1 + 266.919X_{2a} + 0.116X_6 \quad (1)$$

(Adj. R^2 0.955 SEE 7.560 t = -4.81, 7.575, 11.258)

where

T = Annual Train Boardings, Melbourne (Millions)
X_1 = real average annual price of full fare Zone 1 ticket
X_{2a} = real average annual price per litre of unleaded petrol (Melbourne) lagged 3 months
X_6 = Estimated resident population in the Melbourne Statistical Division

Using this formula to forecast the number of train boardings calls in the first instance for the the creation of a forecast each of its independent variables. It is to these forecasts that our comments now briefly turn.

The forecast of the real average annual price of full fare Zone 1 ticket is based on the result of a series of time series analyses of the behaviour of the variable over the whole twenty seven year time period of this study and of its annual value over the last fifteen years. A simple three year moving average was also computed for comparative purposes. The polynomial formula set down as (2) is the one used to compute the values of variable X_1 presented in table 6:

$$y = -0.0023x^3 + 0.0565x^2 - 0.2182x + 9.7826 \quad (R^2 = 0.967) \qquad (2)$$

where
y = the real average annual price of full fare Zone 1 ticket
x = year (base year 1995-66).

Forecasting unleaded petrol prices – and indeed petrol prices in general – is a challenging task. Presumably, the analysis of petrol price movements will yield valuable insights. However the time series data used in this study do not provide much forecasting guidance. The straight line trend imposed on the X_{2a} annual data series yields an R^2 of only 0.234 for the entire twenty seven year period. Over the shorter span of 1995-6 to 2009-10 the straight line time series trend line produces an R^2 of 0.734. In the same way, polynomial trend line analysis of the annual behaviour of variable X_{2a} over the twenty seven years of this study does not yield trend lines with high R^2: for instance the polynomial equation to the power of four only yields an R_2 of 0.741. However over the more recent fifteen year period stating 1995-6 the polynomial function shown in equation (3) does produce a usable forecasting equation.

$$Y = -0.0003x^3 + 0.00215x^2 - 0.01808x + 0.41673 \quad (R^2 = 0.946) \qquad (3)$$

where
y = Real average annual price per litre of unleaded petrol lagged 3 months
x = year (base year 1995-66).

The resultant forecasts of the real cost per litre of petrol in Melbourne lagged 3 months income are presented at Table 6, third column.

The task of forecasting X_6, the final explanatory variables in equation (1) is less daunting given the quite consistent and virtually linear nature of the changes in the time horizon of this study. The last column of Table 6 present the resultant time series base forecast that are computed based on equation (4):

$$y = 0.0499x^3 - 1.323x^2 + 43.4x + 2832 \quad (R^2 = 0.9978) \qquad (4)$$

where:
y = estimated resident population Melbourne Statistical Division (000s)
x = year (base year is 1983-4).

Table 6: Forecasts of selected explanatory variables

Year	Real price Zone 1 weekly full fare	Real price/ litre ULP Melbourne lagged 3 months	Est. Resident Population
2011-12	11.34	0.555	4105
2011-12	11.11	0.583	4195
2012-13	10.75	0.593 [1]	4291

Note:

1. Forecast of real price of unleaded petrol in 2012-13 (lagged 3 months) has been reduced from 0.613 to 0.593.

The forecast values in Tables 6 have been incorporated into formula 1 to forecast the value of train boardings over the same five year period. The results are presented in Table 7.

The forecasts patronage levels presented in Table 7 are quite different from those presented in Odgers (2009). The main reasons for the difference are that (i) the earlier forecasts were based on the use of only two independent variables and a linear time series forecasts of the values of both independent variables; (ii) the earlier forecasts were based on a twenty five year period ending 2007-08; (iii) the values of variables X5 to X5b were based on values published by the Reserve Bank of Australia (RBA) based on a previous methodology; and (iv) current rather than real value were used for the average price of a zone 1 ticket and the price per litre of unleaded petrol in Melbourne.

Table 7: Forecast of train boardings (millions) 2010-11 to 2012-13 based on multivariate regression function

Fiscal year	Point estimate Forecast [1]	95% confidence intervals [2]
2010-11	229.4	214.3 to 244.5
2011-12	250.1	235.0 to 265.2
2012-13	268.2	253.1 to 283.3

Notes:

1. Point estimate forecast derived from $T = -258.59-12.095X_1 + 266.919X2_a + 0.116X_6$ (Adjusted R^2 0.955).
2. Following Wilson and Keating (2009): The approximate 95 per cent confidence interval for the true value of the dependent variable Y can be calculated as: $\hat{Y}$ forecast value ± 2(SEE). SEE for the regression equation (1) is 7.56 as shown in table 5.

To test the plausibility of these multivariate regression function forecasts, a number of forecasts based on time series analyses of annual train boardings were performed. The time series equation chosen (equation 5) and resultant forecasts are presented in Table 8. In comparison to the regression forecast, the time series based forecast project a stronger rate of patronage growth.

$$y = 0.0207x^3 – 0.5764x^2 + 5.5307x + 89.491 \qquad (5)$$

(Adjusted R^2 = 0.978; SEE = 5.235)

where

y = Annual train boardings, Melbourne

x = year (1 =1983-4)

Table 8: Forecast of train boardings (millions) 2010-11 to 2012-13: time series

Fiscal year	Point estimate Forecast [1]	95% confidence intervals [2]
2010-11	247.2	236.7 - 257.7
2011-12	270.3	259.8 – 280.8
2012-13	295.8	285.4 – 306.3

7. Official government near term forecasts

The Department of Transport Victoria (2008a) produced the forecasts for the years 2009/10 to 2010/11 for train boardings based on time series analysis of long run data on annual boardings. The methodology used to produce these forecasts is outlined thus.

> *Long run growth rates are applied to the previous year's forecast to calculate the forecast figures. The long run growth rates represent the average annual growth expected over a five year period and will change annually. Growth rates in individual years may be higher or lower than the average. Long run growth rates changed in March 2008* (Department of Transport Victoria 2008a).

The Victorian Department of Transport employs other forecasting methods (Gaymer 2010). One is the use of 'strategic models, such as the four-step Melbourne Integrated Transport Model (MITM) to develop long-term patronage forecasts' (Gaymer, 2010, p. 1). Gaymer (2010, p. 1) reports that in 2008 the Department of Transport Victoria 'also undertook elasticity modelling of (…) patronage growth which could explain most of the observed growth, but around 20% of growth on metropolitan trains remained "unexplained".' Gaymer (2010, p. 4). Of the 80 per cent of patronage change explained through this elasticity model, population growth and petrol prices were estimated to account for around 50 per cent of the increase in average daily patronage (trips per day) over the years 2002 to 2007 (Gaymer, 2010, p. 4).

We suggest that the regression analyses and resultant short-term forecasts presented in this paper are a useful complement to the Victorian Department of Transport's elasticity modelling approach to patronage forecasting as the percentage of variance 'explained' by regression functions in Table 6 is appreciably higher as the 80% explained in the elasticity modelling approach.

8. Overall conclusions and study limitations

The demand for train service in Melbourne has increased quite noticeably in the most recent five years for which annual boardings data are available. Regression analysis of the time series relationship between this transport demand and a number of explanatory variable shows that the two variables with the highest adjusted R^2 values are the average annual housing interest paid as a percentage of household income and the estimated resident population of the Melbourne Statistical Division. Application of a multiple regression equation at the 95% level of confidence, based on the use of three of explanatory variables — the real average price of a zone 1 ticket, the real price per litre of unleaded petrol in Melbourne (lagged 3 months) and the estimated resident population of the Melbourne Statistical Division —indicates that demand will continue to grow with estimated annual boardings of 273.5 million (with a range of 258.8 to 288.7 million) in 2012-13, compared with 219.3 million in 2009-10. This forecast increase equates to an average annual compound rate of growth of some 7.7% per year over the next three years; in comparison the average annual rate of growth in annual train boardings over the years 2006-07 to 2009-10 was 7.1%. The time series forecast presented forebode an even stronger rate of annual patronage growth.

Some of the limitations of this study include those alluded to earlier in this paper. Another limitation is that the analyses of the data are based on and limited to linear modelling techniques. No attempt has been made to identify or capture any non-linear effects. Proposed future research seeks to redress these limitations, provided that the necessary data are available and reliable and that we seek statistical guidance where needed. It is also planned to perform the same analysis on quarterly patronage data and to analyse annual patronage of Melbourne's trams and buses over the same time period.

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