What is Driving Public Transport in Perth: Understanding Determinants and Dynamics?

Abstract

The main objective of this paper is to systematically examine primary determinants that explain both spatial and temporal variations in public transportation use in Perth. It is also to offer a comprehensive and rigorous analysis of use-determinants and develops a robust predictive model based on land use characteristics, urban form, socioeconomic conditions and public transport availability factors which can inform policymaking. It employs the data on revealed preferences derived from smart cards to analyse the variations in temporal and spatial patterns of public transport use in Perth depending on types of patrons, the origin suburbs of their journeys and the day and time of travel.

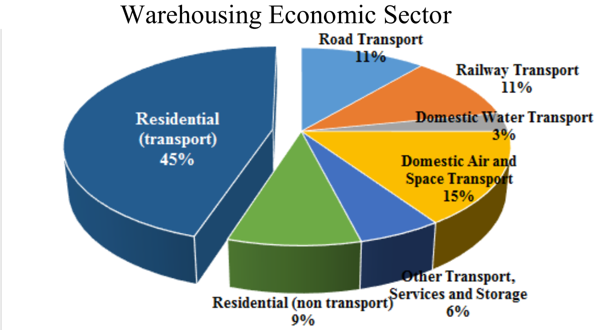
The research deploys factor analysis to identify latent variables among a broad range of explanatory variables and then applies the multiple regression analysis to develop a predictive model of public transport use in Perth metropolitan suburbs. The main finding from this research is that the Bus/Ferry service provision density is the most important factor in explaining the spatial and temporal variations in public transport use in Perth's metropolitan suburbs, along with income factor and land use characteristic (resident and student population density). It also has a practical implication for public transit planning for Perth to increase public transport usage and promote the role of public transit in Perth. Therefore, this paper points out the importance of addressing the combined influences of land use characteristics, socioeconomic factors, and service provision factors in shaping public transport use.

1. Introduction

Perth [1] is the second fastest growing city in Australia, and it is remarkable that its population has grown at a rate of 150% during a period of 40 years 1973-2013, (Australian Bureau of Statistics 2 April 2014b). According to the "Regional Population Growth, Australia, 2008-09 (Western Australia)" report from the Australian Bureau of Statistics (ABS), the population growth rate of WA in 2008-09 was 3.1%. It was higher than Australia's annual average of 2.5% for the five years leading up to June 2009 and also the fastest among all Australian states and territories. In June 2009, (Australian Bureau of Statistics 30 March 2010, pg. 312-313) estimated the resident population of Western Australia at approximately 2.25 million people, and 74% of the state population (1.7 million) was estimated to live in the state's capital Perth. This population growth rate has gradually accelerated in recent years, Perth's at 3.5% between 2012 and 2013 (Australian Bureau of Statistics 2 April 2014a). Further, the population is projected to reach 4.8 million by 2053. Thus, Perth's rapid population growth poses significant challenges for public policy and planning to accommodate increasing demand for housing, transportation, employment, and other community facilities and services.

According to the (Department of Environment-Australian Government n.d), residential transport contributed the highest CO2-e Emissions (45%) in transport, postal and warehousing economic sector for Western Australia in the year 2014.

Figure 1: CO2-e Emissions (Gg) for WA from Transport, Postal and Warehousing Economic Sector



Source: Department of the Environment and Energy, Australia Government, National Inventory by Economic Sector, http://ageis.climatechange.gov.au/ANZSIC.aspx , accessed on 5th March 2017

[1] In this paper, Perth refers to the state capital of Western Australia.

As shown in the following Figure 2, the CO2-e emitted from resident transport in Western Australia has consistently been increasing at its significant rate over the 24-year period. Here, there was significant 61% increase in greenhouse gas emission between 1990 and 2014, from 3,444 to 5,224 Gigagrams. It is noticeable that there were notable increases in CO2-e emission recently which were 6.05% in 2012 and 5.82% in 2014 from the previous years. These substantial increases in CO2 emission from residential transport indicate that there is need to increase the public transport use to shift away from private car use.

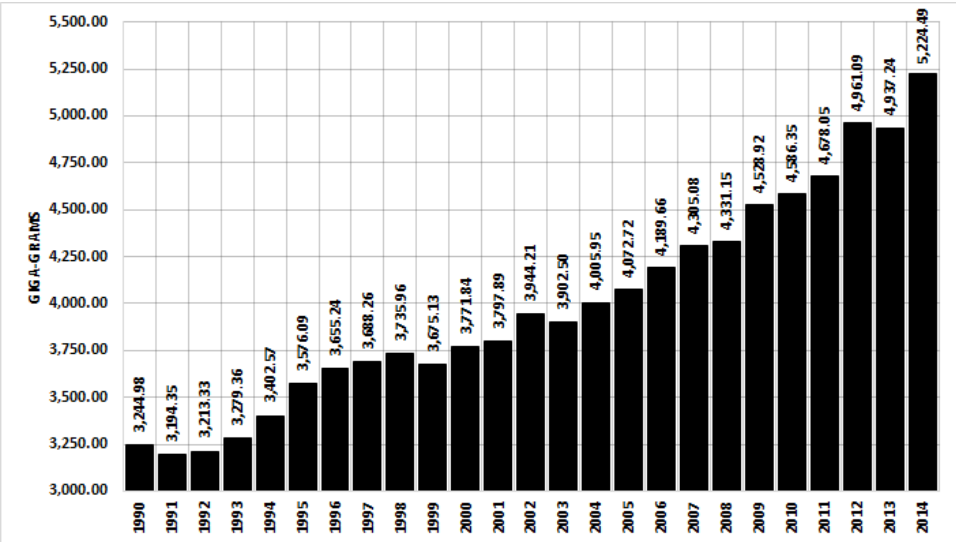


Figure 2: CO2-e Emissions (Gg) for WA from Resident (Transport)
Source: Department of the Environment and Energy, Australia Government, National Inventory by Economic Sector, http://ageis.climatechange.gov.au/Chart_ANZSIC.aspx?OD_ID=1414466292 , accessed on 5th March 2017

Department of Planning and Western Australian Planning Commission August (2010) released the medium term integrated land use and transport plan is laid out in the "Direction 2031". In this scheme, the resident population in Perth's metropolitan suburbs is expected to reach 3.5 million by 2031. It also targets a 50% increase in the current average residential density which will result in 10 dwellings per gross urban-zoned hectare. The (Department of Transport July 2011b) also released a public transport map for Perth for 2031 to project the future of its public transportation network, aligned with the state's "Direction 2031" plan. In this proposed public transport plan

(Department of Transport July 2011a, p.g 6), public transport use is expected to account for:

- "*One in eight of all motorised trips (currently one in fourteen),*
- *One in five motorised trips in the morning peak period (currently one in eight),*
- *Over 30% of peak hour distance travelled (currently around 20%), and*
- *Nearly 70% of all trips to the CBD (currently around 47%)".*

This study examines an extensive amount of information on all suburbs in Perth for one period (2009) for the following reasons:

- To identify the temporal and spatial variations in the public transport usage patterns in Perth metropolitan suburbs in Western Australia;
- To develop a public transport usage function for Perth metropolitan suburbs based on the land use characteristics, socio-economic attributes, urban forms and public transport service provisions; and
- To generate a comprehensive and rigorous regression model to predict the changes in public transport usage based on changes in its determinants.

2. Data

This study integrates wide-ranging dataset to address the research question "*What is driving public transport in Perth*?" Ann enormous number of studies have been conducted over the years to investigate the relationships between public transport use and other factors. Nevertheless, this study brought together the land use characteristics, socio-economic factors, urban form factors, and public transport service provisions together in a systematic way to examine variations in public transport use rates.

The **exploratory variable** used in this study is "public transport usage density" generated from the revealed preference dataset. Public Transport Authority in Perth collects it through SmartRider fare collection systems. The specific measure of public transport usage in this study is generated by aggregating the total number of journeys from their origin suburbs.

The **explanatory variables** used in this study are:

1. public transport service provision variables
   1.1. Average stops per km in each suburb, (Asensio 2000; Bass 2011; Holmgren 2013; Polat 2012) and

1.2. The total frequency of service density (covering total service provided in a whole week for each suburb in Perth), (Barton-Aschman Associates 1981; Balcombe et al. 2004; Curtis and Roger 2011; Dodson, and Neil 2007; Holtzclaw 1994; Mees 2000; Polat 2012; Webster 1982),

2. land use characteristics
    2.1. Estimated resident population density by age and gender in urbanised suburb area (per km^2) (Badoe 2000; Balcombe et al. 2004; Cervero 1991; Cervero and Kara 1997; Mackett 1990; Perkins 2006; Souche 2010; Susilo 2007; White 2009),
    2.2. School student (up to year 12) population density gender in urbanised suburb area (per km^2) (Pitombo 2011; Tolley 1996),
    2.3. University student population density in urbanised suburb area (per km^2) (Curtis and Carlindi 2004a, 2004b; Shannon 2006) and
    2.4. Employment density gender in urbanised suburb area (per km^2) (Cervero 1988, 1991, 2002; Ewing 1994; Hendrickson 1986; Schimek 1996),

3. socio-economic attributes
    3.1. Number of residents whose weekly income falls into four different groups in each suburb, (Balcombe et al. 2004; Bresson et al. 2003; Dargay 2002; Holmgren 2013; Pitombo 2011; Thompson 2012),
    3.2. Average monthly rent of each suburb, (Dodson and Neil 2007; Liao 2014; Martinez 2008; Sipe 2006),
    3.3. Average Car ownership per household in each suburb, (Balcombe et al. 2004; Bresson et al. 2004; Cullinane 2003; Greenwald 2006; Kenworthy 1999; McFadden 1974; Mokhtarian 2002; Newman and Kenworthy 1989; Paulley 2006),

4. urban form factors
    4.1. Average street length (in km) gender in urbanised suburb area (per km^2) (Cervero 2001, 2002, 2003; Kenworthy, 1999; Hansen 1993; Mogridge 1990; Zeibots 2005) and
    4.2. Distance from the city centre, (Boarnet and Randall 2001; Boarnet and Sharon 1998; Cervero 2002; Riekko 2005; Sohn 2005; Stead and Marshall 2001; Weber 2003),

The datasets mentioned above were collected from various sources including Transperth, the Australian Bureau Statistics, Landgate, the Western

Australian Department of Planning and the Real Estate Institute Western Australia.

The **suburban and urbanised areas** for each suburb are calculated based on the administrative boundary areas and unurbanised area of each suburbs; provided by the Landgate (the Western Australia Land Information Authority). Agricultural lands, meadow, pastures, regional scale parks, urban forest, wetland and water surfaces are considered as non-urbanised areas and subtracted from the administrative boundary areas to generate the suburban and urbanised areas. This resulting suburban and urbanised areas (in m^2) are used to calculate the density attributes.

2.1 Public Transport Usage Density

SmartRider is the electronic ticketing systems used on Transperth services, Transperth (n.d). Additionally, cash payment is also available from any bus driver or train station. The Public Transport Authority 2009/2010 annual report states that SmartRider covers 70% of all public transport use in 2009. Various types of patronages who are using SmartRider are standard, concession, seniors, pensioners, veterans, students up to year 12 and tertiary students. This study mainly uses the passenger trip records from the SmartRider System, provided by Transperth for Jan-Dec 2009. The unique nature of the dataset used in this research makes the work undertaken in the study an original contribution to the field. In total, the database contained 141.3 million trip segments. The data, therefore, represent millions of public transport trips across the Perth metropolitan region for an entire year, accompanied by additional socio-economic, land use, urban forms, and public transport service timetable data for research investigations. Public Transport Authority (n.d-a, n.d-b) estimated that the SmartRider public transport usage represented approximately 66.1% of the total (2008/2009) annual usage and 69.9% of the 2009/2010 total annual usage, of public transportation in Perth. Therefore the Smartrider data constitute an extremely useful resource for research that has not been exploited before.

The definitions of the measurements for public transport usage in this study are as follow:

- Travel segment is an individual travel transaction which initiates when a patronage gets on board on any public transport mode by tagging on his/her SmartRider card and completes when that patronage alights from it by tagging off his/her smart card.
- The transfer is the act of changing the different public transport modes or the various services of the same mode.

- A journey is a movement between origin and destination, comprised of one or more than one travel segment by taking into account all transfers. In this study, the absolute number of journeys generated at the origin suburb are used as a measurement for the public transport usage in Perth metropolitan suburbs.

2.2 Public Transport Service Provision

Average Stops per km^2: the total number of bus/ferry stops and train stations in each suburb were counted first. Then, the total number of stops and stations that were available in 2009 were divided by the urbanised area of the corresponding suburbs in Perth's metropolitan areas to calculate the average stops per km^2 in each suburb.

Total Frequencies as Public Transport Service Provision: bus, ferry and train timetable dataset in 2009 was used to calculate the public transport service provision variables. The weekly total frequencies of bus/ferry services and train services for each suburb in 18-time segments (3 hours time intervals for weekdays, Saturday and Sunday, except early morning hours on weekdays, Saturday and Sunday) are aggregated first. Then weekly total public transport service frequencies are divided by the urbanised areas to derive their densities in each suburb.

These service provision variables were subsequently used in a factor analysis to examine of how they correlate with each other, and how much each service provision variable contributes to the latent variables produced by the factor analysis.

2.3 Land Use Characteristics

The land use characteristics variables examined in this study include estimated resident population densities, employment-population density, students up to year 12 population density and university student population density.

Estimated Resident Population Density: the Australian Bureau of Statistics provided the "Estimated Resident Population Density in 2009" dataset as customised data from its Information Consultancy Services. The estimated residential population for Perth metropolitan suburbs was collected by gender and four age groups: 0-16, 17-35, 36-64, and 65 years and over. Instead of using the average estimated residential population, this study uses the estimated resident populations densities categorised by age and gender to examine the differential contribution of each of these groups to public transport use in Perth.

Students Up to Year 12 Population Density: students (up to year 12) population data was extracted from Curtin University business intelligent data warehouse at http://planning.curtin.edu.au/bitools/. This dataset includes students enrolment in all schools, along with school addresses, for tow terms in 2009. The variations between the student enrolments in these two terms of each school is very low. The average of student enrolments in two terms was calculated for each school first. Then these student enrolments were agglomerated according to the suburb in the school address. After this, the student enrolments for each suburb were divided by its urbanised area to calculate the population density of students up to year 12. There were 69 suburbs without schools in 2009.

University Student Population Density: A similar process was applied to calculate the university student population data from the Curtin University business intelligent data warehouse, and to compute the average student enrollments in two semesters. Subsequently, the university student populations were divided by the urbanised areas of their corresponding suburbs to generate the university student population density. There were six suburbs which had university student populations which were Crawley, Bentley, Murdoch, Mount Lawley, Fremantle and Joondalup. This university student enrollment dataset was also verified with the student enrollment numbers reported in the Annual Reports from each university in Perth metropolitan areas.

Employment-Population Density: The Department of Planning provided the employment-population dataset from its Perth Employment Survey, which was completed in June 2009. Approximately 113,000 employment activities in the Perth Metropolitan areas and the Mandurah and Murray local government areas were recorded in this employment survey. Both full-time and part-time employment were included in this analysis. There are eleven Planning Land Use Categories identified as types of industries in this research: Manufacturing/Processing/Fabrication, Primary/Rural, Storage/Distribution, Office/ Business, Service, Shop/Retail, Other Retail, Entertainment/ Recreation/ Culture, Health/ Welfare/ Community Services, Residential, and Utilities/ Communications. Subsequently, the employment-population densities in each industry were calculated by dividing the employment-population by the urban area of each suburb.

2.4 Socioeconomic Attributes

The socio-economic variables used in this study are:

- Number of residents in different income groups
- Average car ownership per household
- Average weekly rent [2].

Number of Residents in Different Income Groups: income dataset is collected from the Australian Bureau of Statistics. The majority of datasets used in this study were collected in 2009. However, two censuses for income dataset for 2009 are the 2006 census and 2011. Of these two census years, the number of residents whose weekly income data collected in 2011 is used in this study because it is closer to 2009 than 2006. This dataset is categorised into four different income group as (1) weekly income below \$250, (2) between \$250 and \$1000, (3) between \$1000 & \$2000, and (4) above \$2000. Instead of average weekly income in each suburb, the number of residents in the four different weekly income groups was used to determine each group's differential contribution to public transport usage.

Car Ownership per Household: car ownership data is collected from 2011 Census. Referring to the (Australian Bureau of Statistics 20 May 2011), the number of households is counted based on the number of motor vehicles parked at its premises at census night. The total number of registered motor vehicles is divided by the number of dwellings to compute the average car ownership per household in each suburb.

Average Monthly Rent: the historical rental dataset in Perth metropolitan suburbs is collected from REIWA (Real Estate Institute of Western Australia) at http://reiwa.com.au/the-wa-market/suburb-rentals-search/. Rental data were collected based on the various rental properties listed and leased in 2009. All different types of dwellings, such as townhouses, units, duplexes and villas, were included in this data collection.

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[2] Average weekly mortgage was included in the initial data analysis stage. Nevertheless, the correlation between average weekly rent and average weekly mortgage is significantly high and these two variables are almost identical. Average weekly rent is more appropriate to select because this dataset is available annually and will allow for validation and verification with other studies in the future.

Only residential rentals were taken into account for enumerating the average monthly rent in each suburb while commercial rentals were excluded.

There were eight suburbs for which socio-economic factors were insignificant: Welshpool, Karrakatta, Perth Airport, Malaga, Neerabup, Malaga, Carabooda, and Kwinana Beach, as a result of their very low estimated resident population densities. However, employment densities in these suburbs were significant, as they are industrial areas. In this research, not only the estimated resident population densities but also employment densities and student population densities, are considered as determinants of public transport usage. Therefore, these eight suburbs are still included in this research even though they have insignificant socioeconomic factors because of very low estimated resident population densities.

2.5 Other Urban Form Variables

Two urban form variables taken into account in this research are road length (in km) per km^2 and distance from city centre.

Road Length (in km) per km^2: Landgate (Western Australia Land Information Authority) provided the road centerline dataset. All road types, such as closed road, minor road, road, street, freeway, and highway are included; the lane counts, however, are not considered in computing the total road length in km. Then total road lengths (in km) per km^2 is calculated for each Perth metropolitan suburbs based on their urbanised area.

Distance from City Centre: Landgate (Western Australia Land Information Authority) provided the suburb administrative boundaries dataset. Perth Central Business District consists of Perth and East Perth suburbs, Landgate (2009). Therefore, this distance from city centre is used as an interchangeable measurement as the distance to Central Business District. The distance to city centre is calculated as direct distances between the centroid of Perth suburb polygon and the centroid of other suburb polygons because Perth suburb is the city centre of Perth metropolitan area.

3. Methods and Findings

3.1 Methods

The study deploys factor analysis to identify latent variables among a broad range of explanatory variables and then applies the multiple regression analysis to develop a predictive model of public transport use in Perth metropolitan suburbs. This study uses exploratory factor analysis based on the principal component analysis; applying with Varimax factor rotation, to examine the latent factors among public transport service provision densities as well as among land use characteristics and their socioeconomic attributes. Then these latent factors and other determinants are used in the regression model.

3.2 Spatial Variation in Public Transport Usage by Suburb

The public transport usage is agglomerated based on the origins of each suburb from the SmartRider dataset. First, all tag on, and tag off transactional data are transformed into journal details. A journey can be comprised of one or more than one segment because people can use more than one mode of public transport to complete a journey. This study includes 293 suburbs in Perth metropolitan areas where Transperth provides the public transport service. Some suburbs, such as Kings Park, Whiteman Park, Tamala Park, Burns Beach, and Medora Bay, are recreational venues or environmental reserves and excluded from this analysis.

Figure 3 Top 30 Suburbs for Public Transport Usage Including Perth suburb in 2009

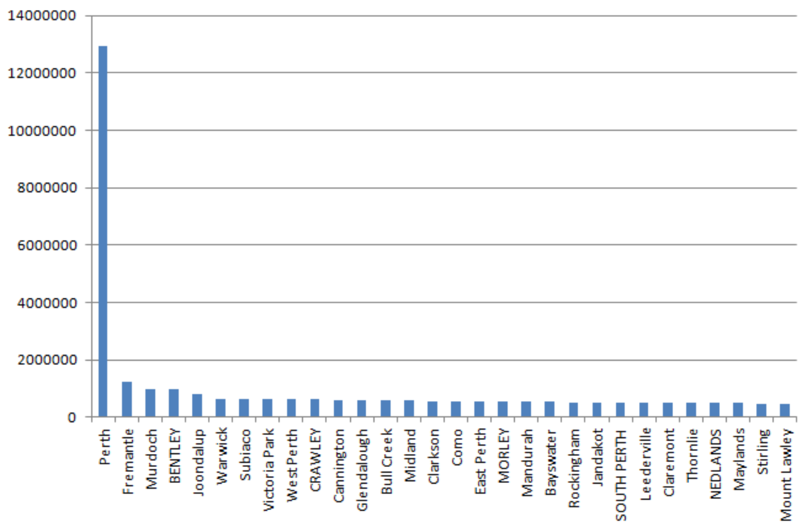


Figure 3 illustrates the top thirty suburbs where the number of trips originated in Perth suburb is significantly higher than the rest of the suburbs in Western Australia during the year 2009. It is mainly driven by its significantly high employment density. Statistically, Perth suburb can be considered as an outlier in the data analysis. Nevertheless, the Perth suburb cannot be excluded due to its significance in land use characteristics and socioeconomic factors.

Figure 4: Top 50 Suburbs for Public Transport Usage Excluding Perth Suburb in 2009

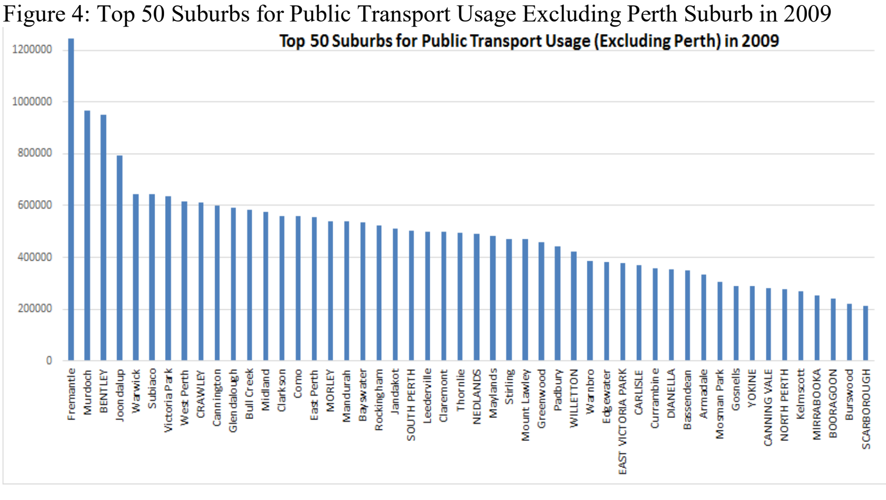


Figure 4 shows the top 50 suburbs for public transport usage excluding Perth suburb in 2009 to gain better understanding and comparison of the variation in their usage. The above figure shows that the suburbs where the universities are located such as Fremantle, Murdoch, Bentley, Joondalup and Crawley are among the top 10 suburbs with high public transport usage.

In this study, activity population is an aggregate measure of estimated resident population, employment-population, student (up to year 12) population and university student population. The public transport usage per capita is used to clarify whether this high public transport usage is due to high activity population density and to demonstrate the importance of distinguishing aggregate from per capita trends.

Figure 5: Public Transport Usage per Capita in Western Australia Suburbs Map

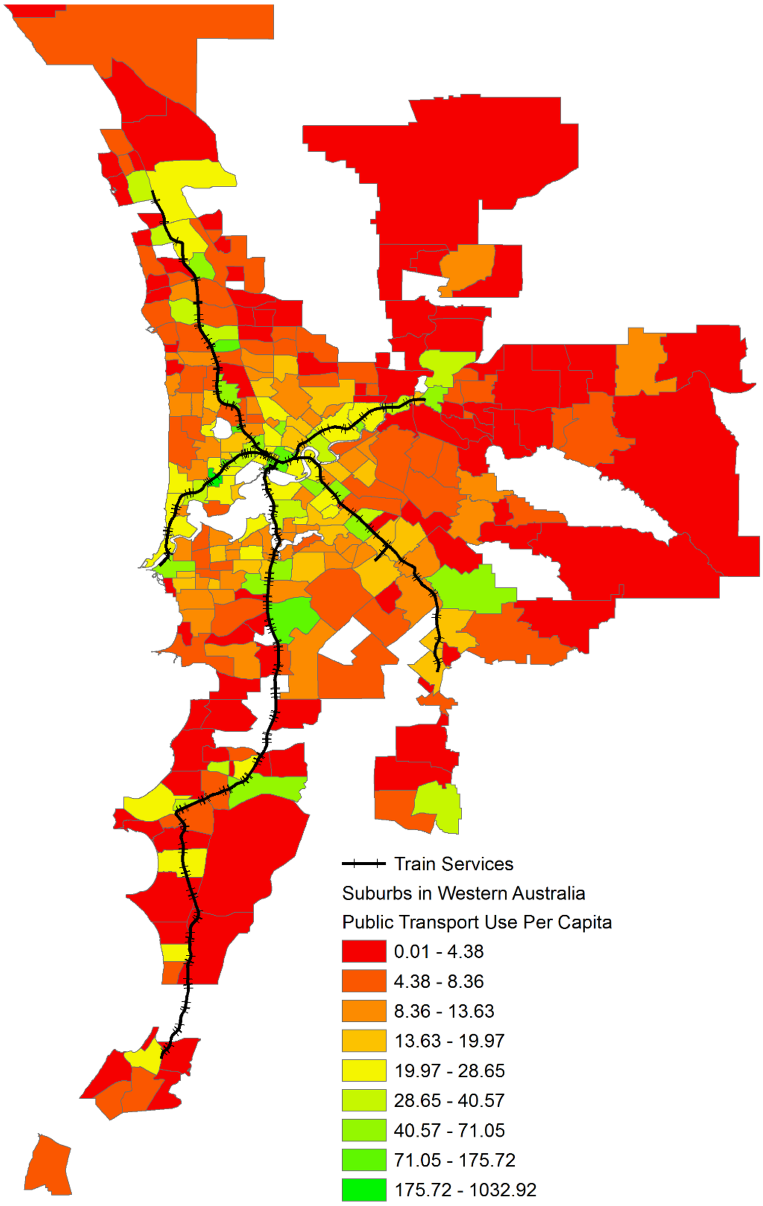


Figure 5 illustrates public transport usage per capita in the Perth metropolitan suburbs. It shows that public transport usage per capita is higher along the train lines when these suburbs are closer to the city centre, whereas per capita usage decreases as suburbs get farther away from the central business district.

3.3 Temporal variation in Public Transport Usage

This section elucidates temporal variation analysis of how different groups of patrons used public transportation on a monthly basis in 2009.

Figure 6: Monthly Public Transport Usage Patterns in 2009 by Different Types of Patrons

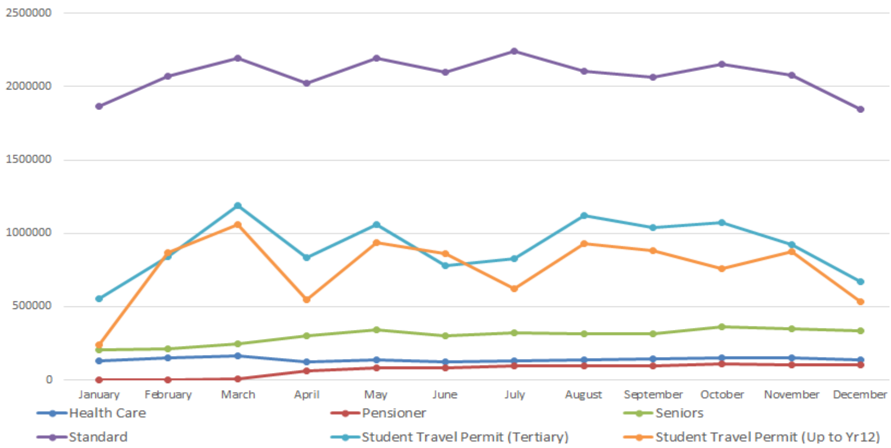


Figure 6 shows the public transport usage by different types of patrons in each month of 2009. The standard patrons, who are the regular adult riders and not eligible for any concession, are the ones who used the public transport most in 2009, followed by university students and other students up to year 12. There is no significant fluctuation in the pattern of usage by standard patrons throughout the year except slight decreases in December and January. In contrast, the public transport usages by university students and other students (up to year 12) are significantly low in January and December. Their usages fluctuate throughout the year depending on school/university study period. Moreover, public transport usage by seniors, healthcare concession holders, and pensioners are relatively low compared to the other patron groups. However, their usage patterns are relatively stable throughout the year.

Figure 7: Number of trips by 3 hours periods of weekdays (by different types of patrons)

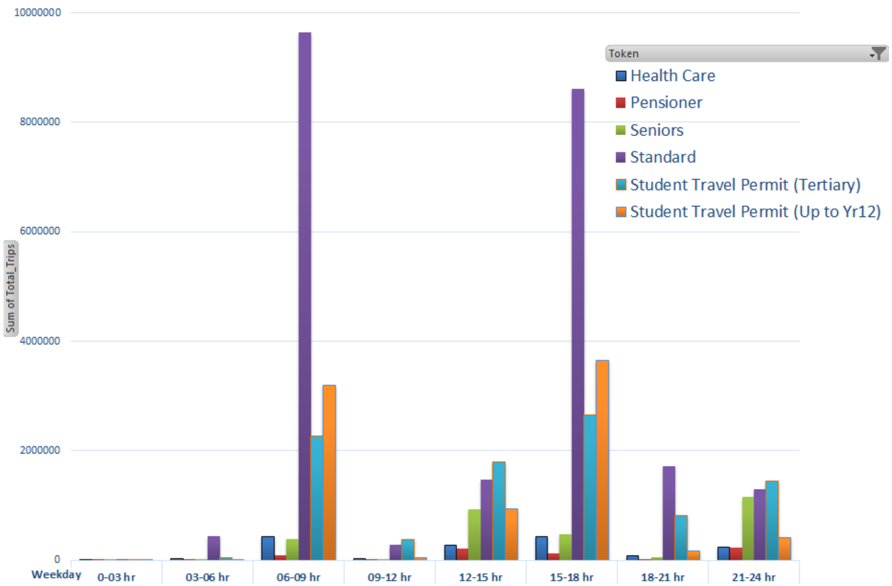
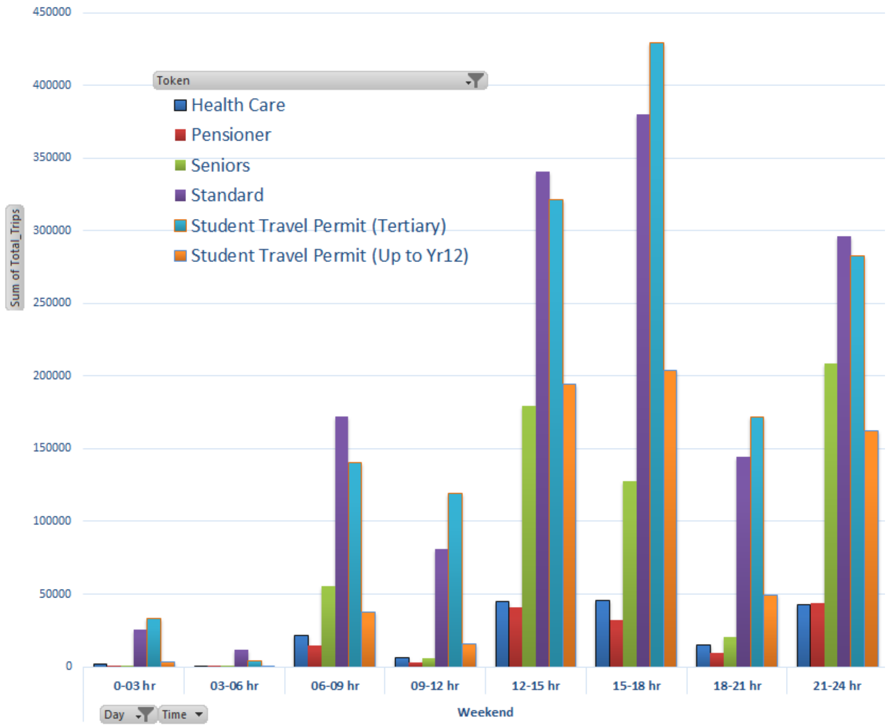


Figure 7 illustrates the comparisons the number of trips by 3 hours period of weekdays by various patronage groups. As expected, 6-9hr and 15-18hr are the peak hours for public transport use while it is at a minimum during the 0-3hr period, followed by 3-6hr and 9-12hr. Public transport use by standard patrons during the morning peak hours (6-9hr) was approximately the same as the total usage during 15-21hr. Their usage in the morning and evening peak hours were remarkably higher (more than twice) than the other patrons. However, their usage on weekdays decreases significantly during 9-12hr after the morning peak hours. Moreover, their usages are nearly the same during afternoon 12-15hr and late evening periods 18-21hr and 21-24hr.

On weekdays, the students (up to year 12) mainly used public transport during morning and evening peak hours. Public transport usage by students (up to year 12) was higher than that of university students during 6-9hr and 15-18hr. The university students used public transport more than students (up to year 12) during the afternoon period 12-15 hr, as well as during evening periods (18-21hr and 21-24hr). Additionally, their usage in afternoon hours (12-15hr) was the highest among all patron groups. Moreover, their nighttime (21-24hr) public transport usage was even higher than their late evening one (18-21hr).

The other patrons' usage was relatively very low compared to that of standard and student groups. Pensioners' usage was the lowest, followed by those using healthcare benefits. Interestingly, seniors' public transport use on weekdays was the highest in the 9 pm- midnight period, followed by 12-15hr. When their usage data was drilled down in the data warehouse, it was found that Perth, Burswood and Fremantle were the top 3 suburbs where they started their trips during 9pm-midnight throughout the whole year of 2009. Their usage during morning and evening peak hours were, by contrast, relatively low. Another unusual pattern here is that usage by seniors and students (up to year 12) was nearly the same during the period from 9 pm till midnight.

Figure 8: Number of trips by 3 hour periods on weekends (by different types of patrons)



The above Figure 8 illustrates the public transport usage patterns by various patron groups during 3 hours periods on weekends. It shows that the public transport usage patterns on weekends were quite distinct from the ones on weekdays. The only similarity is that the usage was the lowest during the 12am-3am and 3am-6am periods. Overall, the usage during the morning period 6am-9am was higher than 9am-12non. It then increased dramatically in all patron groups during 12noon-3pm and 3pm-6pm, before falling from 6pm-9pm. This usage then increased again in the night period (9pm-till midnight) to more than double that of the late evening period (6pm-9pm).

All patron groups followed the same public transport usage patterns on weekends. Additionally, standard patrons were the most frequent users during the morning (6am-9am), 12noon-3pm, and 9 pm until midnight periods. University students were also frequent users on weekends. Usage by students (up to year 12) and seniors was relatively low compared to the standard and university student groups.

Table 1: Maximum Public Transport Usage by Different Types of Patronages

Type of Patronages	Month	Day	Time	Suburb	Max Public Transport Usage
Standard	July	Weekday	15-18 hr	Perth	573283
Student Travel Permit (Tertiary)	March	Weekday	15-18 hr	Perth	86416
Seniors	October	Weekday	12-15 hr	Perth	27376
Student Travel Permit (Up to Yr12)	March	Weekday	15-18 hr	Perth	25649
HealthCare	March	Weekday	15-18 hr	Perth	18944
Pensioner	October	Weekday	12-15 hr	Perth	4875

Table 1 summarises the maximum public transport usage for different patrons across month, day, time and location of boarding. In 2009, standard patrons most frequently used public transport on weekdays in July from 3 pm and 6 pm and boarded from Perth. The maximum public transport usage by university students, students (up to year 12) and healthcare patrons was from 3 pm and 6 pm on weekdays in March, and they also boarded in Perth. For pensioners and seniors, the highest public transport usage took place from 12noon to 3 pm on weekdays in October. As the table indicates, Perth was the most frequent starting point for all patron groups—Perth being the suburb that provides the most public transport services.

3.4 Composition of Public Transport Usage by Different Types of Patrons

In this section, the composition of public transport usage by various types of patrons is discussed to identify which group contributed the most towards the total public transport usage in 2009.

Figure 9: Percentage of Public Transport Use Percentage by Different Types of Patrons

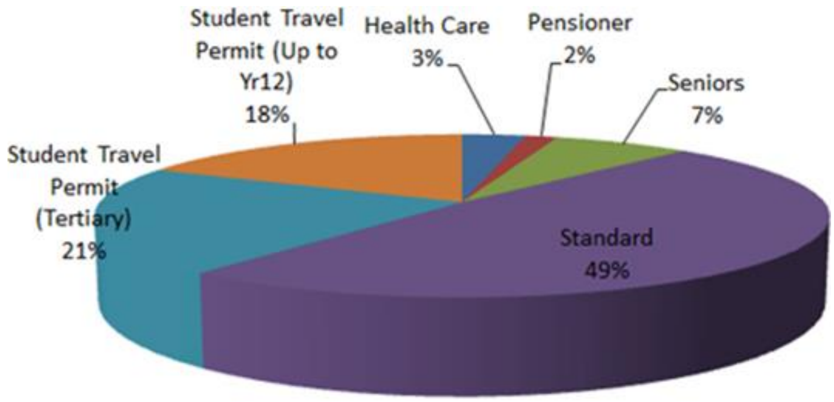


Figure 9 shows that the standard patron group has the highest percentage share of total public usage and accounts for 49% of it. It is followed by university students, who as a group account for 21% of total public transport usage. The usage of other students (up to year 12) is relatively similar to that of university students, accounting for 18% of total usage. It is also noticeable that the figures for health care beneficiaries and older adults are relatively low. Together, the total contribution from healthcare, pensioner and senior patronage groups accounts for only 12% of the overall usage,—even lower than that of students up to year 12.

3.5 Factor Analysis on Public Transport Service Provision Densities

Factor analysis is also conducted to identify any latent variables among weekly public transport service provision densities within 3 hours periods on weekdays and weekends.

Table 2: Rotated Component Matrix from Factor Analysis on Public Transport Service Provisions

Rotated Component Matrix[a]

	Component	
	1	2
Train Service Provision_Density_PerKm2_Saturday 15-18hr	.956	
Train Service Provision_Density_PerKm2_Saturday 9-12hr	.956	
Train Service Provision_Density_PerKm2_Saturday 12-15hr	.956	
Train Service Provision_Density_PerKm2_Weekday 9-12hr	.955	
Train Service Provision_Density_PerKm2_Saturday 0-9hr	.955	
Train Service Provision_Density_PerKm2_Sunday 12-15hr	.955	
Train Service Provision_Density_PerKm2_Sunday 15-18hr	.955	
Train Service Provision_Density_PerKm2_Sunday 9-12hr	.955	
Train Service Provision_Density_PerKm2_Saturday 18-21hr	.954	
Train Service Provision_Density_PerKm2_Weekday 12-15hr	.954	
Train Service Provision_Density_PerKm2_Weekday 21-24hr	.953	
Train Service Provision_Density_PerKm2_Saturday 21-24hr	.953	
Train Service Provision_Density_PerKm2_Sunday 18-21hr	.953	
Train Service Provision_Density_PerKm2_Sunday 3-9hr_21-24hr	.952	
Train Service Provision_Density_PerKm2_Weekday 0-6hr	.950	
Train Service Provision_Density_PerKm2_Weekday 18-21hr	.949	
Train Service Provision_Density_PerKm2_Weekday 6-9hr	.935	
Train Service Provision_Density_PerKm2_Weekday 15-18hr	.920	
Bus/Ferry Service Provision_Density_PerKm2_Sunday 18-21hr		.946
Bus/Ferry Service Provision_Density_PerKm2_Sunday 9-12hr		.936
Bus/Ferry Service Provision_Density_PerKm2_Weekday 18-21hr		.932
Bus/Ferry Service Provision_Density_PerKm2_Sunday 12-15hr		.924
Bus/Ferry Service Provision_Density_PerKm2_Sunday 15-18hr		.917
Bus/Ferry Service Provision_Density_PerKm2_Weekday 21-24hr		.899
Bus/Ferry Service Provision_Density_PerKm2_Saturday 15-18hr		.882
Bus/Ferry Service Provision_Density_PerKm2_Weekday 6-9hr		.881
Bus/Ferry Service Provision_Density_PerKm2_Saturday 12-15hr		.873
Bus/Ferry Service Provision_Density_PerKm2_Weekday 15-18hr		.869
Bus/Ferry Service Provision_Density_PerKm2_Saturday 0-9hr		.864
Bus/Ferry Service Provision_Density_PerKm2_Saturday 18-21hr		.859
Bus/Ferry Service Provision_Density_PerKm2_Weekday 12-15hr		.859
Bus/Ferry Service Provision_Density_PerKm2_Saturday 9-12hr		.856
Bus/Ferry Service Provision_Density_PerKm2_Weekday 9-12hr		.852
Bus/Ferry Service Provision_Density_PerKm2_Saturday 21-24hr		.789
Bus/Ferry Service Provision_Density_PerKm2_Sunday 3-9hr_21-24hr		.772
Bus/Ferry Service Provision_Density_PerKm2_Weekday 0-6hr		.697

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

Based on the above Table 2, we can formulate the two public transport service provision densities latent factors as:

$$\begin{aligned}
&\mathit{Train\ service\ Provision\ Factor} \\
&\quad = .956T1_i + .956T2_i + .956T3_i + .955T4_i + .955T5_i + .955T6_i \\
&\quad + .955T7_i + .955T8_i + .954T9_i + .954T10_i + .953T11_i + .953T12_i \\
&\quad + .953T13_i + .952T14_i + .95T15_i + .949T16_i + .935T17_i \\
&\quad + .952T18_i
\end{aligned}$$

$$\begin{aligned}
&\mathit{Bus/ferry\ service\ Provision\ Factor} \\
&\quad = .946B1_i + .936B2_i + .932B3_i + .924B4_i + .917B5_i + .899B6_i \\
&\quad + .882B7_i + .881B8_i + .873B9_i + .869B10_i + .864B11_i + .859B12_i \\
&\quad + .859B13_i + .856B14_i + .852B15_i + .789B16_i + .772B17_i \\
&\quad + .697B18_i
\end{aligned}$$

Where:

T1	=	Train Service Provision_Density_PerKm2_Saturday 15-18hr
T2	=	Train Service Provision_Density_PerKm2_Saturday 9-12hr
T3	=	Train Service Provision_Density_PerKm2_Saturday 12-15hr
T4	=	Train Service Provision_Density_PerKm2_Weekday 9-12hr
T5	=	Train Service Provision_Density_PerKm2_Saturday 0-9hr
T6	=	Train Service Provision_Density_PerKm2_Sunday 12-15hr
T7	=	Train Service Provision_Density_PerKm2_Sunday 15-18hr
T8	=	Train Service Provision_Density_PerKm2_Sunday 9-12hr
T9	=	Train Service Provision_Density_PerKm2_Saturday 18-21hr
T10	=	Train Service Provision_Density_PerKm2_Weekday 12-15hr
T11	=	Train Service Provision_Density_PerKm2_Weekday 21-24hr
T12	=	Train Service Provision_Density_PerKm2_Saturday 21-24hr
T13	=	Train Service Provision_Density_PerKm2_Sunday 18-21hr
T14	=	Train Service Provision_Density_PerKm2_Sunday 3-9hr and 21-24hr
T15	=	Train Service Provision_Density_PerKm2_Weekday 0-6hr
T16	=	Train Service Provision_Density_PerKm2_Weekday 18-21hr
T17	=	Train Service Provision_Density_PerKm2_Weekday 6-9hr
T18	=	Train Service Provision_Density_PerKm2_Weekday 15-18hr
B1	=	Bus/Ferry Service Provision_Density_PerKm2_Sunday 18-21hr
B2	=	Bus/Ferry Service Provision_Density_PerKm2_Sunday 9-12hr
B3	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 18-21hr
B4	=	Bus/Ferry Service Provision_Density_PerKm2_Sunday 12-15hr
B5	=	Bus/Ferry Service Provision_Density_PerKm2_Sunday 15-18hr
B6	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 21-24hr
B7	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 15-18hr
B8	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 6-9hr
B9	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 12-15hr
B10	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 15-18hr
B11	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 0-9hr
B12	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 18-21hr
B13	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 12-15hr
B14	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 9-12hr
B15	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 9-12hr
B16	=	Bus/Ferry Service Provision_Density_PerKm2_Saturday 21-24hr
B17	=	Bus/Ferry Service Provision_Density_PerKm2_Sunday 3-9hr and 21-24hr
B18	=	Bus/Ferry Service Provision_Density_PerKm2_Weekday 0-6hr

3.6 Factor Analysis on Land Use Characteristics and Socio-Economic Attributes

Factor analysis is also used to extract latent land use characteristics and socioeconomic factors from the estimated resident population densities by age and gender, student (up to year 12) population density, the number of residents from different weekly income groups, average rent, and average car ownership per household in each suburb. Three latent variables are identified among fifteen land use characteristics and socio-economic attributes.

Table 3: Rotated Component Matrix from Factor Analysis on Land Use Characteristics and Socio-Economic Attributes

Rotated Component Matrix[a]

	Component		
	1	2	3
Estimated Resident Population Density Age: 36-64 (Male)	.941		
Estimated Resident Population Density Age: 36-64 (Female)	.934		
Estimated Resident Population Density Age: 17-35 (Female)	.900		
Estimated Resident Population Density Age: 17-35 (Male)	.875		
Estimated Resident Population Density Age: 65 and over (Male)	.871		
Estimated Resident Population Density Age: 65 and over (Female)	.824		
Estimated Resident Population Density Age: 0-16 (Female)	.821		
Estimated Resident Population Density Age: 0-16 (Male)	.819		
Student Population Density	.503		
No of Residents Whose Weekly Income Between 250 and 1000		.954	
No of Residents Whose Weekly Income Below 250		.928	
No of Residents Whose Weekly Income Between 1000 and 2000		.923	
No of Residents Whose Weekly Income Between Above 2000		.557	.423
Average Rent			.879
Average Car Ownership Per Household			.712

Extraction Method: Principal Component Analysis.

a. Rotation converged in 5 iterations.

Based on Table 3, the equations for three latent variables among all land use characteristics and socio-economic attributes can be formulated as:

$$Resident\ and\ student\ Population\ Density\ Factor = .941SE1_i + .934SE2_i + .9SE3_i + .875SE4_i + .871SE5_i + .824SE6_i + .821SE7_i + .819SE8_i + .503SE9_i$$

$$Income\ Factor = .954I1_i + .928I2_i + .923I3_i + .557I4_i$$

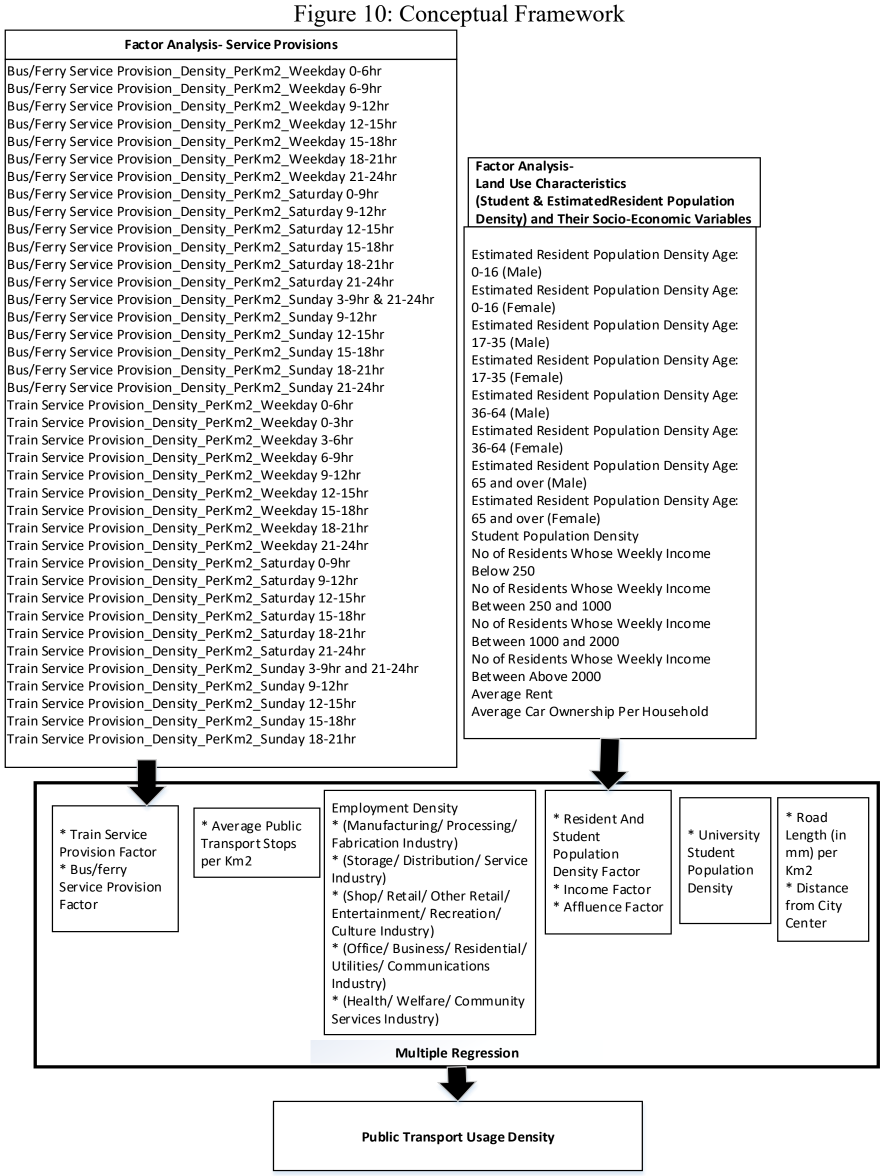
$$Affluence\ Factor = .423A1_i + .879A2_i + .712A3_i$$

where:

SE1	=	Estimated Resident Population Density Age: 36-64 (Male)
SE2	=	Estimated Resident Population Density Age: 36-64 (Female)
SE3	=	Estimated Resident Population Density Age: 17-35 (Female)
SE4	=	Estimated Resident Population Density Age: 17-35 (Male)
SE5	=	Estimated Resident Population Density Age: 65 and over (Male)
SE6	=	Estimated Resident Population Density Age: 65 and over (Female)
SE7	=	Estimated Resident Population Density Age: 0-16 (Female)
SE8	=	Estimated Resident Population Density Age: 0-16 (Male)
SE9	=	Student Population Density
I1	=	No of Residents Whose Weekly Income Between 250 and 1000
I2	=	No of Residents Whose Weekly Income Below 250
I3	=	No of Residents Whose Weekly Income Between 1000 and 2000
I4/A1	=	No of Residents Whose Weekly Income Between Above 2000
A2	=	Average Rent
A3	=	Average Car Ownership per Household

3.7 Multiple Regressions with Different Combinations of Observed Variables

Figure 10: Conceptual Framework



Based on the conceptual framework as shown in Figure 10, six different multiple regression models, using different combinations of observed variables, are thoroughly examined to gain a better understanding of which determinants are important in explaining public transport use, and of which contribute most to the development of a predictive model.

Before conducting the multiple regression analysis, the curve estimates are calculated to identify whether the dependent variable and independent variables have linear or non-linear relationships.

Table 4: Summary of Curve Estimates between Dependent Variable and Predictors

Curve Estimate												
Dependent Variable: Public Transport Usage per Km2												
	Linear		Logarithmic		Quadratic		Cubic		Power		Exponential	
Independent Variable	R Square	Sig.	R Square	Sig.	R Square	Sig.	R Square	Sig.	R Square	Sig.	R Square	Sig.
Train Service Provision Density Factor+1.	0.317	0.000	0.078	0.000	0.700	0.000	0.836	0.000	0.117	0.000	0.114	0.000
Bus/Ferry Service Provision Density Factor	0.316	0.000	0.054	0.000	0.680	0.000	0.801	0.000	0.523	0.000	0.264	0.000
Average Public Transport Stops Per Km2.	.168	0.000	.054	0.000	.191	0.000	.304	0.000	.743	0.000	.530	0.000
Employment Density (Manufacturing/ Processing/ Fabrication Industry)+1.	.019	.019	.038	.001	.054	0.000	.063	0.000	.054	0.000	.008	.124
Employment Density (Storage/ Distribution/ Service Industry)+1.	.032	.002	.045	0.000	.082	0.000	.083	0.000	.141	0.000	.028	.004
Employment Density (Shop/ Retail/ Other Retail/ Entertainment/ Recreation/ Culture Industry)+1.	.283	0.000	.083	0.000	.302	0.000	.712	0.000	.517	0.000	.144	0.000
Employment Density (Office/ Business/ Residential/ Utilities/ Communications Industry)+1.	.609	0.000	.114	0.000	.790	0.000	.865	0.000	.420	0.000	.096	0.000
Employment Density (Health/ Welfare/ Community Services Industry)+1.	.561	0.000	.091	0.000	.721	0.000	.851	0.000	.441	0.000	.102	0.000
Students and Mid-aged Dominant_Resident Population Density Factor+2.	.047	0.000	.039	.001	.051	.001	.051	.002	.591	0.000	.501	0.000
University Student Population Density+1.	.023	0.010	.020	.015	.023	.034	.024	.069	.043	0.000	.026	0.000
Below $2000 Weekly Earner Dominant_Income Group Factor+3.	.000	0.812	.001	.694	.000	.967	.004	.747	.069	0.000	.067	0.000
Affluence Factor+4.	.006	.191	.001	.662	.007	.350	.012	.343	.001	.543	.035	.001
Road Length in km per km2.	.062	0.000	.034	.002	.096	0.000	.105	0.000	.654	0.000	.600	0.000
Distance from City Center+1.	.043	0.000	.162		.095	0.000	.151	0.000	.394	0.000	.276	0.000

Table 4 illustrates that the most significant relationships between public transport usage and its predictors are curvilinear (i.e. cubic, power and exponential curves). The minimum values of some variables are deliberately incremented to be greater than 0 to conduct the curve estimates for these relationships. Otherwise, their cubic, power and exponential relationships could not be identified.

The predictors that have the most significant relationships with public transport usage per km2 in cubic form are as follows:

1. Train Service Provision Density Factor

2. Bus/Ferry Service Provision Density Factor
3. Employment Density (Manufacturing/ Processing/ Fabrication Industry)
4. Employment Density (Shop/ Retail/ Other Retail/ Entertainment/ Recreation/ Culture Industry)
5. Employment Density (Office/ Business/ Residential/ Utilities/ Communications Industry) and
6. Employment Density (Health/ Welfare/ Community Service Industry).

The predictors that have a significant power-curve relationship with public transport usage per km^2 are:

7. Average Public Transport Stops per km2
8. Employment Density (Storage/ Distribution/ Service Industry)
9. Student and Mid-aged Dominant Resident Population Density Factor
10. University Student Population Density
11. Below $2000 Weekly Earner Dominant Income Factor
12. Road Length in km per km2 and
13. Distance from City Centre.

These curvilinear relationships between public transport usage and its predictors confirm that it is necessary to transform the data so that the normality and linearity assumptions for multiple regression can be satisfied. Field (2013) suggests two ways for transforming the variables with positive skewness, positive kurtosis and lack of linearity: (1) log and (2) square root transformations.

Table 5 Data Transformation Results

	Mean	Std. Deviation	Skewness		Kurtosis	
			Statistic	Std. Error	Statistic	Std. Error
Public Transport Usage per Km2	46282.32	177171.53	13.27	0.14	200.84	0.28
Log (Public Transport Usage per Km2)	9.12	2.19	-0.95	0.14	1.19	0.28
√ (Public Transport Usage per Km2)	150.68	153.82	4.30	0.14	34.23	0.28
Employment Density (Manufacturing/ Processing/ Fabrication Industry)	24.72	82.94	6.59	0.14	55.13	0.28
Log (Employment Density (Manufacturing/ Processing/ Fabrication Industry))	1.32	1.71	1.17	0.14	0.25	0.28
√(Employment Density (Manufacturing/ Processing/ Fabrication Industry))	8.87	12.24	4.12	0.14	22.91	0.28

Employment Density (Storage/ Distribution/ Service Industry)	33.13	93.25	4.96	0.14	29.13	0.28
Log (Employment Density (Storage/ Distribution/ Service Industry))	1.65	1.80	0.88	0.14	-0.37	0.28
√(Employment Density (Storage/ Distribution/ Service Industry))	7.87	7.71	2.28	0.14	9.32	0.28
Employment Density (Shop/ Retail/ Other Retail/ Entertainment/ Recreation/ Culture Industry)	121.18	294.35	7.72	0.14	80.49	0.28
Log (Employment Density (Shop/Other Retail/ Entertainment/ Recreation/ Culture Industry))	3.36	1.92	-0.22	0.14	-0.78	0.28
√(Employment Density (Shop/Other Retail/ Entertainment/ Recreation/ Culture Industry))	3.22	4.78	2.39	0.14	6.62	0.28
Employment Density (Office/ Business/ Residential/ Utilities/ Communications Industry)	227.98	928.35	8.44	0.14	83.77	0.28
Log (Employment Density (Office/ Business/ Utilities/ Communication/ Residential Industry))	3.38	2.00	0.13	0.14	-0.22	0.28
√ (Employment Density (Office/ Business/ Utilities/ Communication/ Residential Industry))	2.51	4.30	2.86	0.14	10.39	0.28
Employment Density (Health/ Welfare/ Community Services Industry)	42.24	145.59	9.19	0.14	99.52	0.28
Log (Employment Density (Health/ Welfare/ Community Services Industry))	2.42	1.57	0.20	0.14	-0.21	0.28
√ (Employment Density (Health/ Welfare/ Community Services Industry))	4.35	4.84	3.64	0.14	20.98	0.28
University Student Population Density	101.82	970.02	12.61	0.14	175.95	0.28
Log (University Students Population Density)	0.18	1.17	6.76	0.14	45.14	0.28
√ (University Students Population Density)	1.32	10.02	8.95	0.14	88.39	0.28

Data transformation is conducted by applying these two methods and then selecting the one that best satisfies the normality assumption. Field (2013) also explains that the perfect normal distribution has skewness and kurtosis values of 0. The data are more normally distributed (though not perfectly so) when these values are (positively or negatively) closer to 0. Therefore, the method that can transform the data with skewness and kurtosis values closer to 0 is chosen for public transport usage and the other independent variables with high skewness and kurtosis values.

As Table 5 shows, the log transformation method normalises the unequally distributed independent variables, bringing their skewness and kurtosis values closer to 0. Therefore, it can be concluded that this model satisfies the assumption of normality for predictors. The assumption of normality for residual values is discussed in the multiple regression model section.

Table 6: Multiple Regression Models Comparison (with Different Combinations of Observed Variables)

	Model A		Model B		Model C		Model D		Model E		Model F	
	Only Service Provision Factors		Land Use Characteristics		Land Use Characteristics + SocioEconomic Factors		Land Use Characteristics + Service Provision Factors		Land Use Characteristics + Service Provision+ Socio Economic		Land Use Characteristics + Service Provision+ Socio Economic	
R Square	0.83		0.74		0.76		0.86		0.86		0.87	
Adjusted R Square	0.83		0.74		0.75		0.86		0.86		0.86	
ANOVA (F)	461.11		116.53		96.03		172.71		147.11		127.21	
ANOVA (Sig)			.000b		.000b		.000b		.000b		.000b	
Durbin-Watson	2.01		1.59		1.61		1.99		1.94		1.90	
Coefficient			B	Sig.	B	Sig.	B	Sig.	B	Sig.	B	Sig.
(Constant)	2.73	0.00	6.28	0.00	5.98	0.00	3.35	0.00	3.11	0.00	2.67	0.04
Log (Weekly Train Service Provision Density Factor)	0.16	0.00					0.14	0.00	0.14	0.00	0.14	0.00
Log (Weekly Bus/Ferry Service Provision Density Factor	0.75	0.00					0.56	0.00	0.54	0.00	0.54	0.00
Log (Average Public Transport Stops Per Km2)	0.57	0.00					0.34	0.00	0.34	0.00	0.30	0.01
Log (Employment Density (Office/ Business/ Utilities/ Communication/ Residential Industry))			0.23	0.00	0.21	0.00	0.12	0.02	0.12	0.01	0.10	0.04
Log (Employment Density (Shop/Other Retail/ Entertainment/ Recreation/ Culture Industry))			0.23	0.00	0.17	0.01	0.10	0.03	0.07	0.16	0.07	0.14
Log (Employment Density (Storage/ Distribution/ Service Industry))			0.14	0.11	0.13	0.11	0.09	0.18	0.09	0.17	0.06	0.33
Log (Employment Density (Manufacturing/ Processing/ Fabrication Industry))			-0.19	0.02	-0.17	0.04	-0.19	0.00	-0.18	0.00	-0.16	0.01
Log (Employment Density (Health/ Welfare/ Community Services Industry))			0.13	0.04	0.12	0.06	0.09	0.05	0.08	0.08	0.09	0.07
Resident and Resident Population Density Factor			1.82	0.00	1.96	0.00	0.42	0.01	0.53	0.00	0.42	0.04
Log (University Students Population Density)			0.17	0.00	0.17	0.00	0.12	0.01	0.12	0.00	0.12	0.00
Income Factor					0.80	0.00			0.48	0.01	0.49	0.01
Affluence Factor					-0.28	0.07			-0.04	0.73	-0.05	0.68
Road Length (in m) per Km2											0.09	0.60
Distance from City Center											-0.01	0.05

The coefficient of determination (R Square) values in the above table show that Model F which is derived from all observed variables can explain public transport usage in the Perth metropolitan suburbs better than the others. The coefficient of determination values in Models A (only public transport service provisions are considered) and Model B (only land use characteristics are considered) can be interpreted as service provision factors explain more variation in public transport use than do land use characteristics alone. The R-square value for Model C (both land use characteristics and socio-economic variables are considered) is slighter higher than for Model B, which indicates that combining socio-economic and land use characteristics can improve the model marginally. However, when service provision factors are considered along with land use characteristics, the predictive power of the model increases noticeably, from 0.74 to 0.86. Finally, the R-square values in Model E and F indicate that including service provision factors along with land use characteristics, socio-economic and urban forms factors as explanatory variables accounts for the largest amount of variation in the dependent variable. The difference between Model E and F is that the road length (in m) per km^2 and distance from city centre are included in Model F. Nevertheless, their contributions to determine the public transport use is not significant compared to other explanatory variables. This finding reflects on

Figure 5 which illustrates public transport usage per capita in the Perth metropolitan suburbs. The public transport usage per capita is higher in the suburbs along the train lines.

The results from the Durbin-Watson test also confirm that taking the service provision factors into account improves the model by better satisfying the assumption of auto-correction. When service provision factors are excluded, the Durbin-Watson test values are substantially less than 2 (closer to 1.5). However, when service provision factors are combined with the land use characteristics, socio-economic, and other urban form factors, the Durbin-Watson test value in Model F gets closer to 2 (at 1.9) indicating the improvement in the fitness of model.

4. Conclusion and Policy Implications

Many previous studies have confirmed the critical role of land use characteristics, socio-economic attributes, urban forms, and public transport service provisions in determining the public transport use. Nevertheless, the strength and significance of these variables' effects vary substantially depending on where and how these previous studies are conducted. Handy (2005) recommends considering an extensive repertoire of explanatory variables to gain a better understanding of their nuanced relationships with public transport demand. Therefore, this study follows her recommendation for more inclusive approach, which allows gaining a more nuanced and granular understanding of how their synergistic influences can account for the differential in public transport usages across Perth metropolitan suburbs. The policy implications based on these findings will be discussed at three different levels such as strategic, tactical and operational levels.

4.1 Strategic Level Recommendations

The findings from this study show that l*and use characteristics, urban form, socio-economic factors, and service provisions factors should not be considered in isolation since*, depending on which explanatory variables are considered in the model, the significance and magnitude of a given variable can be changed. Additionally, the empirical findings from this study relating to employment density are noteworthy because *employment densities only have significant relationships with public transport use in certain industries*. Specifically, *employment densities in the office, business, utilities, communication and residential industry category are very strong determinants of public transport use*, reflecting their high employment densities in the CBD (22% of total employment in these industries are located in the CBD) and high service provision. Accordingly, this result confirms that the presence of high employment densities in the CBD, which is the target area for high provision of public transport service, is highly conducive to higher usage, thus highlighting the *importance of integrating mixed land use development and a sustainable transportation system*.

The findings from this study illustrate that the income factor (which is mainly dominated by the number of residents whose weekly income is below $2000) is the second most influential determinant of the public transport usage variations in Perth. On the other hand, the relationship between the public transport usage density and the affluence factor (constituted by high average car ownership, average rent, and the number of residents whose weekly income is above $2000) is negative, but this relationship is not statistically significant. Therefore, this study recommends that *policymakers should also target the areas where there are a high number of residents whose weekly income is below $2000*.

Therefore, at the strategic level, it is important that policymaker should consider *integrating public transportation and land use planning to facilitate sustainable transportation outcomes in conjunction with social, economic, and environmental benefits while reducing transportation and other disadvantages in the outer suburbs. Integrated public transportation (more frequent bus services integrated with train services) should also be provided to the areas with high student and resident population densities, as well as to the areas where there is a high density of people with weekly incomes below $2000.*

4.2 Tactical Level Recommendations

The following factors should be taken into account at tactical level:

a) Integrating modes of public transport in a system with feeder bus services for the suburbs that have very low public transportation usage per capita and no direct access to train services at farther distances from city centre,
b) Evaluation of the public transport service stop-placement efficiency and service network density—especially bus stops, because the majority of public transport stops are bus stops in Perth metropolitan suburbs). This evaluation should be accompanied by improvements to bus service provision; policymakers should monitor and increase the use of public transport services.

4.3 Operational Level Recommendations

The following factors need to be considered to improve the public service provision to attract or encourage more public transport usage at the operational level are:

a) More frequent service provision based on the peak hours of patrons with standard smart cards, particularly on weekdays when school is in session,
b) More frequent service provision in the morning periods from 6-9am and 12noon until midnight during the weekends, which will encourage greater public transport use for weekend activities.

4.4 Future Research

Every study has limitations as a result of theoretical frameworks, such as choice of research method and paradigm, and practical constraints such as data availability, field setting, and different physical, socio-economic, and cultural backgrounds of the areas that are researched. Apart from these issues, the present study also faces some methodological limitations regarding measurements and models. Therefore, these limitations need to be carefully identified so that we can refine future research agendas and expand our knowledge of public transport systems.

It is important to model potential patrons' profiling to identify the suburbs or public transport service routes where public transport service provisions should be increased. Students including university and up to year 12 are also major users of public transport contributing 39% of the public transport usage in 2009. A current research is being conducted to model Curtin Universtiy students' study trips by profiling based on the location or suburbs where these students reside and the places where they study. Public transport service routes which need to be increased to be more attractive for new student patrons and also to encourage existing patrons to use public transport could be identified.

Additionally, Liao (2014) suggest using structural equation modelling to examine endogenous relationships among socio-demographic~~s~~, attitudinal, and residential preferences. Therefore, another research is also being conducted to apply the Structural equation modelling, combined with confirmatory factor analysis, path analysis, and latent growth modelling, to identify the latent variables and their interrelationships, as well as their causal effects.

In this paper, spatial autocorrection has not been observed. Thus, it is planned to conduct spatial autocorrection analysis to examine whether public transport utilisations in Perth metropolitan suburbs are similar to each other. Moreover, Ma (2013) performed a comparative analysis of the efficiency and accuracy of five data mining algorithms to classify patrons and measure their loyalty to public transport usage. If regularities are discovered for different types of patrons, they can be used with site selection criteria from different kinds of businesses to facilitate decision support systems. Therefore, it is also planned to apply clustering algorithm and neural network method as a future research to identify suitable locations for businesses based on the places to which their targeted customers travel most.

8. References

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