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Competition between busways and heavy rail system in South East Queensland, Australia

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Abstract

Brisbane's busways in Queensland, Australia are a form of bus rapid transit (BRT) that comprises high capacity buses running on prioritised routes, similar to a rail system. In South East Queensland (SEQ), some busways (e.g., South East Busway) run parallel with heavy rail in ways that these two modes are in essence competitive with each other. This paper explores the inter-modal competition of busway and rail passengers' travel patterns by analysing revealed preference data, the smart card transaction records directly extracted from automated fare collection system. The results indicate that busways are more competitive than heavy rail due to more frequent service with higher accessibility to the stations. The simulation analysis shows that if the heavy rail could increase service frequency or station accessibility, it would significantly increase the mode share of heavy rail. The policy implications suggest that service frequency and integration with feeder bus service to stations are critical to inter-modal competition between busways and heavy rail system.

1. Introduction

Brisbane in Queensland, Australia, has one of the world's largest and most efficient busway networks. Mostly on segregated rights-of-way, with an average stop spacing of about 1.2 kilometres (longer spacing at the periphery and shorter spacing near the city centre) and many express services, the busways offer travel into the central business district (CBD) from the north and south of the city. As with the rail network, the SEQ busway network offers passengers faster, more frequent and reliable bus services. Some of these busways operate parallel to the heavy rail lines with relatively low bus-rail integration. For example, the South East Busway is parallel to the Beenleigh rail line (see Figure 1) supporting many bus routes that cross the train line before running on the busway. To some extent, these two modes are in nature competing with each other for passengers. Busways can provide a wider coverage (more than 100 routes operating in the South East Busway alone) with higher accessibility through greater penetration and by high service frequency. In contrast, the heavy rail lines are not integrated with feeder buses, only provide limited stations with accessibility restricted to passengers living in the immediate vicinity and serve less frequency (30-minutes frequency for most lines, albeit at greater frequencies in the inner- to middle-suburbs and during peak hours) than nearby buses.

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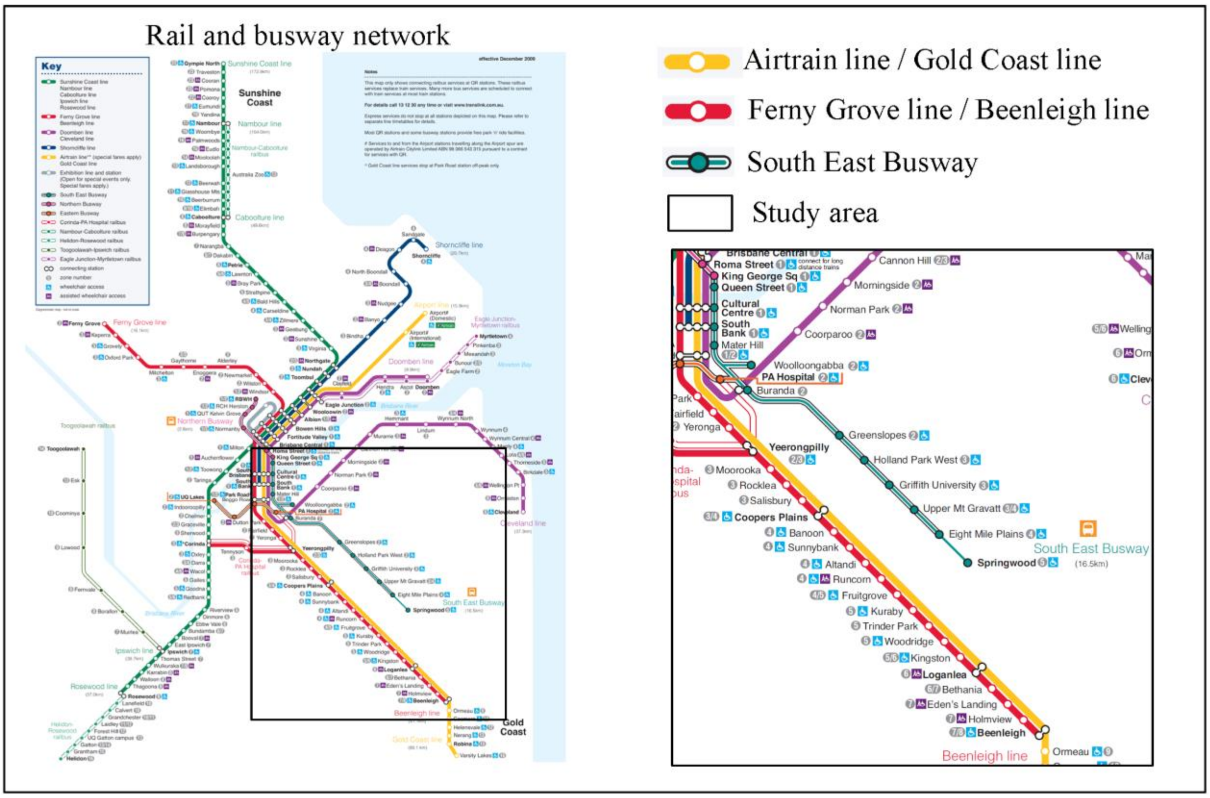

Figure 1 Heavy rail and busway network in South East Queensland, Australia (Source: TransLink)

Evaluating competition in the public transport market, both intra-modal and inter-modal competitions have been addressed in literature. For the intra-modal competition, Mackie et al. (1995), Ellis and Silva (1998), Reeven and Janssen (2006), and Gomes-Lobo (2007) identify as an outcome of the British experience that a critical issue in competition is the competition between operators on quality or frequency rather than on price. Van Reeven and Janssen (2006) further find that destructive competition is unlikely to happen on longer distance services because passengers are more appreciative of their preferred service quality Previous studies have considered inter-modal competition although many of these relate to competition between high speed rail and airline travel (Janic, 1993; Bhat, 1997; Koppelman and Wen, 2000; Gonzalez-Savignat, 2004; CEC, 2006; Park and Ha, 2006; Roman et al., 2007; Ortuzar and Simonetti, 2008; Friebel and Niffka, 2009; Adleret al., 2010; Dobruszkes, 2011; Behrens and Pels, 2012; Dpbruszkes et al., 2014) and not between modes within a given city.

In terms of methodologies, the investigation of inter-modal competition has been undertaken using discrete choice modelling to investigate determinants of mode choice (Bhat, 1997; Koppelman and Wen, 2000; Gonzalez-Savignat, 2004; Park and Ha, 2006; Roman et al., 2007; Ortuzar and Simonetti, 2008; Behrens and Pels, 2012); network competition modelling (Janic, 1993; Adleret al., 2010); and service impact analysis (CEC, 2006; Friebel and Niffka, 2009; Dobruszkes, 2011; Dpbruszkes et al., 2014). Discrete choice modelling has been used in the literature to measure competition in terms of the total journey time (i.e. access time, waiting time and travel time), service frequency and fares are common variables in these studies. Most of these studies have concluded that travel time is the most important mode choice determinant. For network competition between high speed rail and air transport, Janic (1993) first developed a network competition model by minimising total system costs for both passengers and transport operators. Alder et al. (2010), on the other hand, built at network competition model to look at the impact of maximsing overall social welfare. Perhaps a different aspect of competition is seen by the use of impact analysis, examining the effects of fares (CEC, 2006; Friebel and Niffka, 2009) and travel time (Dobruszkes,2011; Dobruszkes et al., 2014).

As interesting and useful as they may be, the above studies nevertheless raise two problems. First, there is only limited literature which investigates inter-modal competition within a city between busway and heavy rail networks. This is maybe because it is expected that modes within a city might be integrated. However in SEQ, the busway system is almost entirely Category A (as with the heavy rail), using fully segregated and physically protected rights-of-way (Vuchic, 2007:51) with 27 busway stations and an average of 1.2 km spacing. Unlike local bus services, the SEQ busway system in fact operates more like a rail system and thus does compete with the heavy rail system to some extent. What seems to be lacking in literature, however, is an in-depth exploration of this kind of inter-modal competition. The second problem is that most previous studies rely on travel surveys to measure inter-modal competition which gives rise to questions as to whether the survey is valid in terms of measuring behaviour change (does the survey itself change behaviour, differing response rates, coding, questionnaire design and self-selection through the recruitment process, etc. (Stopher et al., 2007)). The paper is using the objective measure of transaction data, as identified by the automated fare collection - smart card - technology to evaluate passengers' travel behaviour and thus inter-modal competition. In light of this, the objective of this paper is to measure the competition between busway and heavy rail systems and to use the estimation results to define the degree of competition by simulating improvement policies to see how they influence market share.

The remaining parts of this paper are structured as follows. Section 2 describes level of service (LOS) for both the busway and heavy rail networks in SEQ. Section 3 conducts an empirical study and the results together with discussion. The penultimate section analyses the change in passenger behaviour that might be anticipated through the simulation of different policies and impact of this on market share with respect to service frequency, accessibility, and feeder bus service provision. The final section concludes with avenues for further research.

2. Busway v.s. railway services in Brisbane

In Brisbane, the busway network operates as buses separated from general traffic. In other words, Brisbane's busways are a form of bus rapid transit (BRT) that comprises high capacity buses with distinct branding on prioritised routes, with stations at wider spacing and thus have similar operating characteristics to light rail transit (LRT) systems (Hoffman 2008; Tanko and Burke, 2013). Brisbane's busway network, aka "Quickway" model of BRT, is provided with two-lane rights-of-way supporting 80km/h travel on most of the network, and with passing lanes at all busway stations (Hoffman, 2008). Further, the busways provide more than these BRT type services with a network of local and express bus services for the radial network.

In 2003, Brisbane City Council and Brisbane Transport introduced a "BUZ" concept into the busway network with high frequency routes (express routes): 10-minute headways in peak hours and 15-minute at most outside the peak. Consisting of 20 high frequency routes, this BUZ network covers large parcels of Brisbane without direct access to the heavy rail system as well as large sections of what would generally be understood as the rail catchment, with the consequence that many bus routes have drawn patronage away from Brisbane's heavy rail network (Neelagama, 2014). The busways have proven successful with more than 300 buses per hour running on key links of the South East Busway (north of Woolloongabba) carrying approximately 20,000 passenger per hour[1] in peak periods.

Brisbane's heavy rail network, branded as Citytrain, stretches from Brisbane to the Gold and Sunshine Coasts, and to Ipswich (see Figure 1 above). There are eleven lines with over 600 km of track and 220 km of route service. The heavy rail network is radial with most of the lines connecting in the Brisbane's CBD. Unlike the busways that are well connected by the local bus, only a few rail stations are serviced by feeder buses, in particular in the Brisbane area where the Brisbane City Council operated buses mostly head towards the busways or into the city on the road network.

From the opening of the first section of the busway, between the CBD and Woolloongabba, in September 2000 and the second section between Woolloongabba and Eight Mile Plains in April 2001, there has been an upward trend in patronage. Figure 2 shows the busway and heavy railway passenger numbers in Brisbane[2] from 1999 to 2013 and excludes the extension of the busway to Springwood which was completed in mid-2014. In sharp contrast to the heavy railway service, the busways have achieved an increasing market share and patronage growth. The total number of public transport passengers in Brisbane has increased from approximately 91 millions in 1999 to 148 millions in 2013. Whilst heavy rail patronage has risen significantly in other Australian cities, especially Melbourne, in Brisbane patronage has stagnated. Figure 2 suggests that the development of busways has had considerable competitive effects on the heavy railway system by taking considerable market share, which calls for an in-depth analysis to test this hypothesis.

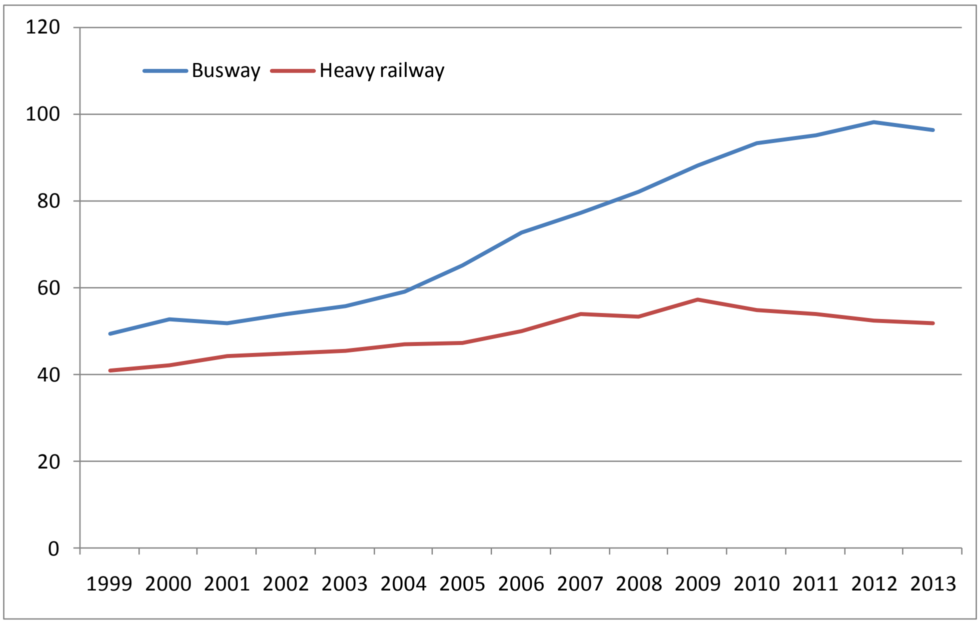

Figure 2 Historical trends in public transport patronage (millions of passengers), Brisbane, 1900 to 2013 (Source: Cosgrove (2011), BITRE (2014) and BITRE (2012)).

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[1] Given the maximum capacity of a majority of Brisbane Transport buses is 62 passengers.

[2] The majority of public transport trip in South East Queensland (SEQ) are made by Brisbane residents that are 70% of SEQ population. Brisbane accounts for 84% of all public transport trips (700,000 trips) in 2009 (Queensland Government, 2012).

3. Empirical study

In order to conduct an empirical study of the competition between the busway and the heavy rail network in SEQ, the South East Busway (from Roma Street to Springwood station) and Beenleigh/Gold Coast line (from Roma Street to Loganlea station) in Figure 1 are chosen as the study area, partly as this is the most mature of the busway corridors. The catchment area for busway and heavy rail station is defined by a 2-km buffer on either side of the station, sufficient to capture all samples access to stations given that the 85th percentile accessibility to Brisbane bus stops and rail stations are 1.07 km and 1.57 km, respectively, according to South East Queensland household travel surveys (Burke and Brown 2007).

3.1 Data

The data used for the analysis come primarily from three sources. First, a one month (March 2013[3]) cross-sectional slice of Go-card transaction dataset, provided by TransLink[4], is used to obtain objective travel behaviour data. In this month of March 2013, there were approximately 15 million transaction records with around 90 per cent of these being in SEQ. A sampling is used for computational reasons and to meet eligibility requirements of statistics software. The selected observations, constituting approximately 0.15 per cent of the Go-card transaction dataset, include around 23,000 trip-based observations after removing 5.6 per cent of incomplete records. Within the 2-km buffer on either side of the busway and heavy rail stations, a total of 19,615 trip-based observations remain for analysis.

In this empirical study, only passengers who travel via Brisbane's CBD to Springwood are selected (Figure 1). The trip characteristics are derived from Go-card data, including the spatial, temporal, cardholder and operational characteristics. The spatial characteristics of trips include travel zone number(s), boarding zone and travel direction (inbound or outbound) of each trip. Figure 3 shows the TransLink SEQ service areas and fare zones. The variable 'Travel zone number(s)' is the number of zone(s) travelled in each trip and is used to capture travel distance characteristic. The variable 'Boarding zone' for each trip is used to capture the distance of the boarding location to Brisbane's CBD (zone 1) and to capture neighbourhood characteristics. For example, boarding at zone 1 as compared to zone 4 will imply different public transport service levels. As a result of zonal boundaries, it is important also to note the travel directions and so two variables identify the two travel directions, inbound and outbound [5]. The 'travel cost' variable is derived based on travel zone number(s) using the zonal fare system of SEQ. The temporal characteristics are identified by travel time, week day trip and peak hour trip [6]. The trip ID, which identifies the cardholder characteristics, also identifies the trip sequence within a journey. Whether or not it is a commuter trip is also one of the cardholder characteristics, counted by the Go-card ID base. Those individuals making a minimum of 24 trips per month are viewed as commuters and all their trips are treated as commuter trips.

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[3] March 2013 is selected due mainly to no public holiday or school break in this month.
[4] TransLink coordinates bus, train (heavy rail), ferry and light rail services throughout SEQ.
[5] Some bus stops and rail stations are located on a zone boundary, so they have two zones (for example, Burpengary is zone 7/8). This means that when travelling towards Brisbane (inbound) the lower zone is used to calculate the fare and when travelling away from Brisbane (outbound) the higher zone is used.
[6] Travelling between 3:00am and 9:00am; and 3:30pm and 7:00pm on weekdays.

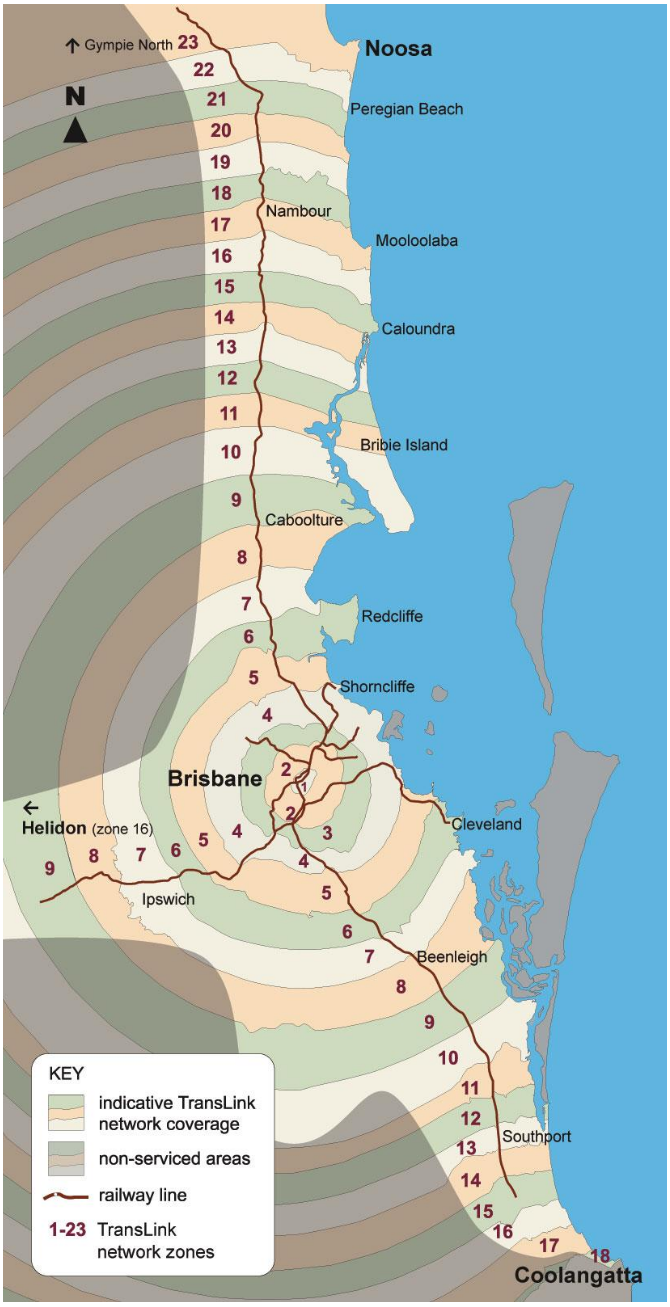

Figure 3. TransLink South East Queensland service areas and zones (Source: TransLink)

This study needs to introduce a number of public transport service variables to define service attributes for each public transport mode, including feeder bus services and heavy rail service frequency. The operational variable relating to the feeder bus trip in this dataset is identified by whether or not a particular trip connects to heavy rail or busway station. The mode of feeder trips will always be bus. For other variables, Geographic Information System (GIS) is used to calculate feeder bus stop density within 2-km buffer on either side of the busway and heavy rail stations. This variable is used as a proxy for the feeder bus service level on the basis that higher feeder bus stop density will be associated with a better feeder service frequency. The service frequency to each heavy rail station is derived from the time table and it is recorded as a daily frequency.

For neighbourhood variables, this study uses the 2011 Census data at the Statistical Area Level 1 (SA1), which is the smallest unit geography. The SA1 units generally have a population between 200 to 800 persons, with an average of about 400 persons. The variables obtained from Census data are used to represent passengers' socio-economic characteristics including population density of the home location; and percentages of population with dependents, who are employed, who are students attending school (under 15 years old), with high income (more than $1,500 per week), dwellings where there are more than two cars, and people using public transport as major travel mode. The percentages here is calculated by SA1 unit. For example, the percentage of dependents is the total number of dependents divided by the total population in each SA1. Table 1 shows the descriptive statistics of the above three categories of variables used in this study, including minimum, maximum, mean, standard deviation, skewness, and kurtosis values.

Table 1 Summary of descriptive statistics of variables

Variable	Unit	Min	Max	Mean	Standard Deviation	Skewness	Kurtosis
Trip characteristic							
Travel time	Minute	1.03	398.87	22.84	14.44	2.83	44.66
Travel cost	Dollar	1.34	6.54	2.09	0.48	1.34	6.34
Trip id	Number	1.00	4.00	1.17	0.42	2.42	6.08
Peak hour trip	Dummy	0.00	1.00	-	-	-	-
Weekday trip	Dummy	0.00	1.00	-	-	-	-
Commuter trip	Dummy	0.00	1.00	-	-	-	-
Feeder bus trip_ Busway	Number	0.00	2.00	1.37	0.77	0.74	0.96
Feeder bus trip_ Heavy rail	Number	0.00	2.00	1.08	0.27	3.13	7.79
Travel zone*	Number	1.00	17.00	2.63	1.35	1.74	9.29
Boarding zone**	Number	1.00	4.00	1.51	0.94	1.97	3.42
Travel direction***	Dummy	0.00	1.00	-	-	-	-
Public transport service							
Feeder bus stop density_Busway	Number/km	0.00	106.00	9.04	23.64	3.36	10.44
Feeder bus stop density_Heavy rail	Number/km	0.00	44.00	1.21	6.72	5.91	34.14
Frequency	Number	60.00	670.00	576.86	219.46	-1.93	1.38
Social demographic							
Population density	People/10m^2	0.02	398.50	21.94	21.40	10.25	162.94
Dependent	%	0.00	94.00	0.21	0.13	0.84	1.34
Students (< 15 years)	%	0.00	58.00	0.11	0.09	2.23	8.12
Employment	%	0.90	100.00	58.73	12.20	-0.55	0.54
Public transport as main travel mode	%	0.00	50.00	18.99	0.09	0.41	0.14
Car number (more than 2)	%	0.00	87.00	31.16	0.21	0.52	-0.74
High income (>1,500/pw)	%	0.00	47.00	15.70	0.08	0.49	-0.02

*Indicates how many zone(s) each passenger travelled.
**Within the study area there are only 4 zones (i.e., the maximum boarding zone number is 4) and the data selection is based on boarding zone.
*** Inbound trip is set to be 1, and 0 otherwise.

3.2 Travel mode choice model

Travel mode choice is modelled to analyse the passenger's behaviour and hence the competition between busway and heavy rail in the study area. A discrete choice modelling approach is adopted to analyse the modal choice of passengers and characterise individual preferences in relation to travel alternatives. Discrete choice models are the most suitable for this purpose, as they guarantee consistency between the demand function and consumer theory (McFadden, 1974; Gonzalez-Savignat, 2004). Passengers are assumed to choose their travel mode (alternative) to maximise their utility. The utility of each alternative, that is busway or heavy rail in this study, is defined as follows:

$$U_i(a) = \alpha_{ia} + \beta_{ia} \cdot T_{ia} + \lambda_{ia} \cdot P_{ia} + \gamma_{ia} \cdot S_{ia} + \varepsilon_{ia} \quad (1)$$

where $U_i(a)$ is the utility of mode a for passenger i. T_{ia} represents the set of trip characteristic variables of mode a chosen by individual i; λ_{ia} is the set of public transport level of service variables of mode a chosen by individual i; S_{ia} is a vector of socio-economic variables for passenger i who chose mode a. α, β and γ are the parameters to be estimated with ε_{ia} is the error term representing the random part of the utility.

3.3 Results

The results of discrete choice model are summarised in Table 2. Based on the likelihood ratio criterion, the model fits the data appropriately with a value of the adjusted likelihood ratio index $\hat{\rho}^2$ being 0.3741. In general, most variables show the expected sign (i.e. negative impact to utilities for travel time and travel cost) at a significance level of 90% or higher. The alternative of heavy rail is selected as the reference mode because of the lower percentage of market share (18% only) in this sample. Among all variables, only two trip characteristic variables, travel time and travel cost, are generic variables. The alternative utility is expected to be higher with lower travel time and/or travel cost.

Table 2 Estimation results for the mode choice model

Variables	Coefficients (t-value)
Constant	
Bus	15.287(1.729)*
Trip characteristic variables	
Travel time	-1.327(-8.229)***
Travel cost	-2.756(-6.269)***
Trip ID_ busway	0.792 (2.644)**
Trip ID_ Heavy rail	-0.364(-2.274)**
Peak hour trip_ busway	0.272(7.456)***
Peak hour trip_ heavy rail	-0.016(-2.338)**

Table 2 Estimation results for the mode choice model (cont.)

Variables	Coefficients (t-value)
Weekday trip_ busway	1.275(1.928)*
Weekday trip_ heavy rail	0.639(1.992)**
Commuter trip_ busway	0.338(4.136)***
Commuter trip_ heavy rail	1.321(2.321)**
Feeder bus trip_ busway	0.172(6.018)***
Feeder bus trip_ heavy rail	0.113(2.000) **
Travel zone_ busway	-1.925(-1.704)*
Travel zone_ heavy rail	0.534(1.706)*
Boarding ID _ busway	0.274(2.121)**
Boarding ID_ heavy rail	-0.013(-1.980)**
Direction_ busway	7.201(1.946)*
Public transport service variable	
Feeder bus stop density_ busway	3.999(1.896)**
Feeder bus stop density_ heavy rail	2.578(1.945)*
Frequency_ heavy rail	2.381(1.782)*
Social demographic variables	
Population density_ busway	0.435(2.327)**
Population density_ heavy rail	-0.317(-2.028)**
Dependent _busway	-3.905(-1.971)**
Dependent_ heavy rail	-4.115(-1.985)**
Student (< 15 years)_ busway	-2.237(-2.061)**
Student (< 15 years)_ heavy rail	-0.659(-1.893)*
Employment_ busway	2.004(1.719)*
Employment _ heavy rail	2.141(1.816)*
Main public transport_ busway	1.928(2.677)***
Main public transport_ heavy rail	2.073(3.993)***
Car number (more than 2)_bus way	-2.226(-2.112)**
Car number (more than 2)_ heavy rail	-2.191(-1.996)**
High income(>1,500/pw)_bus way	-1.329(-1.801)*
High income(>1,500/pw)_ heavy rail	-1.515(-1.749)*
Final log-likelihood	-245.3263
Likelihood ratio	0.3861
Adjusted likelihood ratio	0.3741

Note: * indicates 0.1 level of significance; ** indicates 0.05 level of significance; *** indicates 0.01 level of significance.

The results reveal the effects of three categories of explanatory variables on the utility of passengers' travel mode choice. All other variables are alternative-specific variables that have different coefficients for each alternatives. A negative value of a coefficient indicates that an increase in the value of this variable decreases the utility for the travel mode and thus decreases the probability of that mode being chosen, all other variables remaining unchanged. In terms of the trip characteristic variable, a positive sign of trip ID for busway and negative sign for heavy rail indicates that passengers prefer to travel by bus if a transfer activity is involved. Passengers seek to minimise travel effort (especially, travel time) required to fulfil their activities (Hensher and Reyes, 2000). In SEQ, the busway provides a more frequent service as compared to heavy rail and this reduces the generalised cost. When service frequencies are higher by bus, the waiting time is reduced at interchange if there is a bus to bus transfer and so travelling by busway minimises travel time and is shown to be preferred by travellers.

The results show the impact of peak hour trip on mode choice is significant and positive for bus passengers but significant and negative for heavy rail passengers. It suggests that passengers prefer bus to heavy rail during the peak. For weekday trips, there is a significant positive impacts on both modes, with a larger effect for busway passengers. Likewise, the commuter trip has positive impacts for both modes but with larger but less significant effect to heavy rail passengers. Taken together this suggests the busway is more competitive than rail if passengers are high frequent users who travel during peak period on weekdays. In terms of the trip operational variable, the feeder bus trip has significant positive impacts for passengers, especially for busway passengers. The feeder bus service is significant and positive for both busway and heavy rail network but with a lower impact to the heavy rail network which may be a consequence of the more limited feeder service provision to this mode.

The results also indicate the importance of the spatial characteristics of trips. The results show that the travel zone number and the boarding ID has different impacts on busway and heavy rail passengers. The travel zone variable, capturing the travel distance characteristic, has a negative and significant impact on busway passengers but a positive and significant impact on heavy rail passengers suggesting longer travel distances leads to a reduction in impact for busway passengers. The boarding ID is used to capture the distance of boarding location, relative to the CBD (Brisbane's CBD is in zone 1) and the impact of this is the reverse of the travel zone variable for both modes. The interpretation here is that as the distance of the boarding location from the CBD increases, passengers tend to choose the busway service as their travel mode with inbound (to city) passengers preferring bus as their travel mode more, as shown by the direction busway variable.

Moreover, the public transport service variables, including feeder bus stop density and heavy rail service frequency, which are used to measure mode service quality have the expected impacts. The feeder bus stop density has a significant and positive effects on both modes but a greater impact on busway passengers. In addition, as might be expected, the utility of heavy rail travel increases with increases in frequency as shown by the positive sign of the heavy rail frequency. In terms of the social demographic variables, passengers travelling from higher population densities prefer to travel by bus. As in SEQ, the average population density is higher around busway stations at 242.1 people/10m^2 than for heavy rail stations where it is on average 215.3 people/10m^2, this suggests busways have better route design because they can access larger amount of passengers than heavy rail. For the other neighbourhood based socio-demographic variables the impact on utility is decreasing for both modes where there are higher percentages of dependents, higher percentages of students, higher percentages of dwellings with more than two cars and higher percentage of the population with high incomes. In contrast, utility increases for both modes with higher percentages of neighbourhood employment and higher percentages of public transport as major travel mode usage.

4. Enhancement of heavy rail

There are a number of reasons why it might be important to increase the mode share of the heavy rail network. Heavy rail is typically good at providing high volume passenger movements. In terms of operating costs only, bus is the least cost mode for low demand, with heavy rail the lowest cost in the high demand range (demand over 30,000 passenger per hour) (Meyer et al, 1965; Allport, 1981). A rail mode, may have a lower operating cost only if it is able to increase its patronage to optimise the use of existing rail infrastructure. Moreover, as the modelling results suggest only 18% of mode share goes to the heavy rail network, improving the modal share might provide capacity relief for the busway (as Figure 2 shows an overall increase in public transport patronage). The demand level of SEQ bus service is expected to be doubled by 2031 (Department of Transport and Main Roads, 2011). Meyer et al. (1965) find that for demand between 5,000 to 30,000 passengers per hour one way, buses minimise operating cost. Currently, the busiest busway station (e.g. Cultural Centre station) can carry approximately 20,000 passenger per hour in a peak hour. In the near future, the busway will be overloaded with serious peak congestion and increasing market share of the heavy rail network can delay the need for radical action in providing more infrastructure.

The low market share is mainly due to infrequent rail services (headway of 30 minutes) and low accessibility (of feeder buses) to the rail stations. This is demonstrated by simulations of two possible public transport policies to enhance heavy rail mode share: first increasing heavy rail service frequency and second, increasing the feeder bus stop density. Whilst changing the travel cost is an alternative way of influencing generalised cost, it is not included here since SEQ has an integrated zone fare system in place and all SEQ public transport modes are charged using the same fares policy.

The simulation results are presented in Figures 4 and 5 and Table 3. We simulate various increases in level of rail service frequency; other things remaining unchanged. Figure 4 shows that an increase in heavy rail service frequency by 76% (i.e. from 30 minutes to 7 minutes) would lead to an equal share of the passenger market between bus and heavy rail. In other words, the low mode share of heavy rail in passenger market is substantially due to its low service frequency.

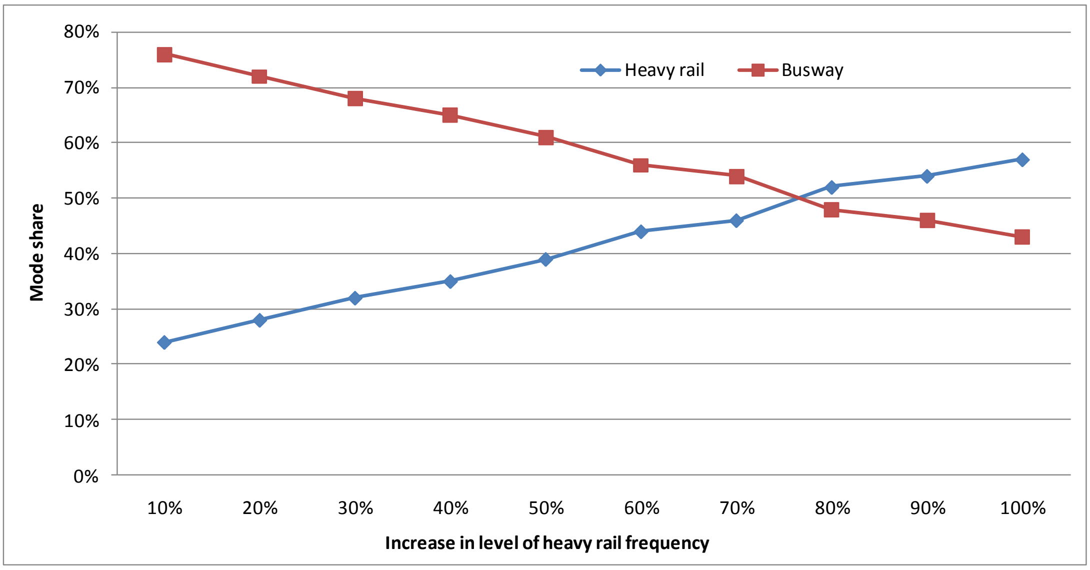

Figure 4 Mode share change in various increase levels of rail service frequency

The second alternative is to improve the accessibility of heavy rail stations by enhancing the feeder bus services. The simulation for this increases the feeder bus stop density within the catchment area of heavy rail stations. Table 3 reports the current feeder bus stop density for both busway and heavy rail stations in different zones. Obviously, busway stations have a higher density level than heavy rail station, especially in zone 1 of Brisbane. However, if it were possible to give the heavy rail network the same level of accessibility? To answer this question, the simulation first increases the feeder bus stop density for heavy rail stations in zone 1 to 45% and to 30% in zones 2-4 within 2-km buffer of heavy rail stations. The simulation results suggest that the mode share of heavy rail would increase from 18% to 32%. Figure 4 further presents the mode share changes in various increase level of feeder bus stop density. Figure 4 shows that the passenger market is shared when the feeder bus stop for heavy rail increases to 75%.

Table 3 Current feeder bus stop density for busway and heavy rail stations

Zone	Busway*	Heavy rail*
1	50.64	36.37
2	13.37	19.95
3	17.24	10.71
4	8.98	8.72

*Unit: number of feeder bus stops/km

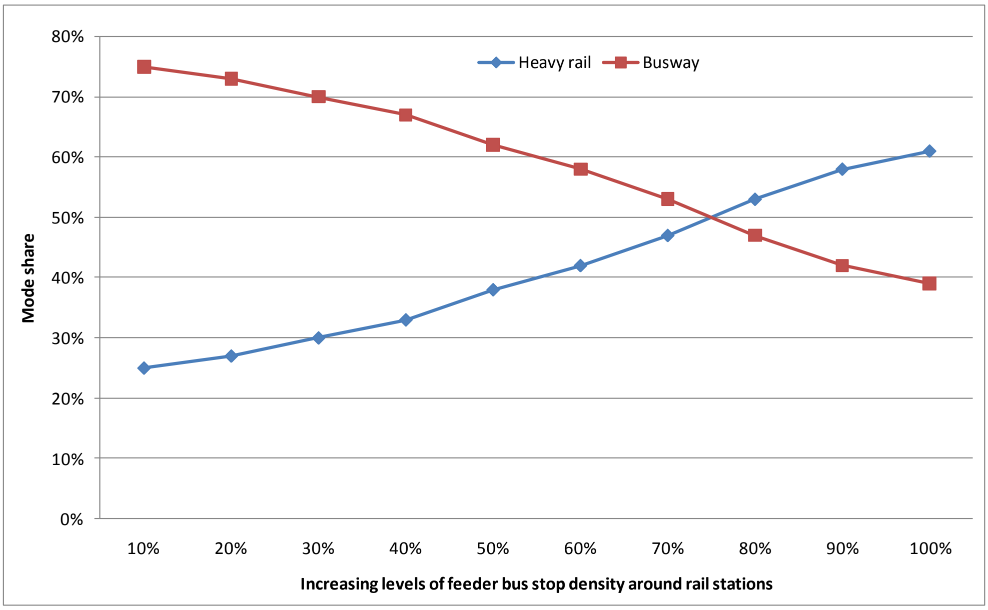

Figure 5 Mode share change in various increase levels of feeder bus stop density

5. Conclusions and discussions

This paper has investigated the competition between the busway and heavy rail systems by modelling passenger travel behaviour in SEQ, Australia. The modelling showed that at a 90% level of confidence (or better) the relative utility associated with each mode alternative was significantly influenced by trip characteristics, public transport service levels and social demographic characteristics. The findings suggest that busway is a more competitive mode for passengers who tend to travel short distances during peak periods on weekdays. Further, high frequency users needing transfers are also more likely to choose busway networks because of the higher service frequency and easier accessibility to the busway station which in turn lowers the generalised cost. Passengers who travel to the city (inbound trips) would also prefer using the busway. The travel mode choice model also provides results in relation to socio-economic variables which are in line with other studies.

This paper contributes to the literature by identifying the degree of market share as a measure of competition in an inter-modal context for a single urbanised area and providing additional case-based evidence. The modelling approach, using discrete choice modelling, provides information as to how different levels influence the utility and the take-up of different public transport options. This allows a better understanding of the drivers of inter-modal competition and suggests some useful policies to improve market share for heavy rail. The alternative policies are further investigated using simulation with results that suggest that the low mode share to rail is substantially due to the low service frequency and inadequate accessibility to stations.

This research points to fruitful areas of further research. These include the investigation of other potential determinants of mode share, including the role of fare policies with perhaps some discount being provided for bus passengers to transfer to heavy rail (as in other countries such as Taiwan), public transport service characteristics (e.g. transit time, frequency, feeder bus service frequency), public transport service type (i.e. express bus, network bus, and/or feeder bus), public transport infrastructure (e.g. park and ride facility), etc. Especially for public transport service characteristics, they can use to investigate the premium between busway and heavy rail systems. Moreover, the spatial variables importance in the results suggest that spatial modelling, perhaps geographically weighted regression, would be useful to control for any inherent spatial dependency. The simulations in this study would be achieved if they are economically viable. A passengers' travel behaviour analysis together with operating characteristics measurement will identify feasibility of potential policies. Finally, further segmentation of peak/off-peak time periods will also be considered as ways of improving model fit.

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