

ASSESSING EFFICIENCY OF A TRANSIT ORIENTED DEVELOPMENT (TOD) BY COMPARATIVE ANALYSIS

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Abstract. Transit oriented developments (TODs) are master planned communities constructed to reduce the dependence on the private car and promote the modes of transport such as public transport, walking and cycling, which are presumed by many transport professionals to be more sustainable. This paper tests this assumption that TOD is a more sustainable form of development than traditional development, with respect to travel demand, by conducting travel surveys for a case study TOD and comparing the travel characteristics of TOD residents with the travel characteristics of residents of Brisbane, Australia who live in non TOD suburbs.

The results of a household comparison showed that the Kelvin Grove Urban Village (KGUV) households had slightly smaller household size, lower vehicle and bicycle ownership compared to Brisbane Statistical Division (BSD), Brisbane's inner north and inner south suburbs. The comparison of average trip characteristics showed that on an average KGUV residents undertook fewer trips on the given travel day (2.6 trips/person) compared to BSD (3.1 trips/person), Brisbane Inner North Suburbs (BINS) (3.6 trips/person) and Brisbane Inner South Suburbs (BISS) (3.5 trips/person) residents. The mode share comparison indicated that KGUV residents used more public transport and made more walk-only trips in comparison to BSD, BINS and BISS residents. Overall, 72.4 percent of KGUV residents used a sustainable mode of transport for their travel on a typical weekday. On the other hand, only 17.4 percent, 22.2 percent and 24.4 percent residents of BSD, BINS and BISS used sustainable modes of transport for this travel. The results of trip length comparison showed that overall KGUV residents have smaller average trip lengths as compared to its counterparts. KGUV & BINS residents used car for travelling farther and used public transport for accessing destinations located closer to their homes. On the contrary, BSD and BISS residents exhibited an opposite trend. These results support the transportation claims of many transport professionals that TODs are more transport efficient and therefore more sustainable in this respect.

Keywords: TOD, TOD residents, comparative study, household characteristics, mode share, trip length.

1. Introduction

Transit oriented development (TOD) is defined here as a fully planned mixed use development equipped with good quality transit service and infrastructure for walking and cycling. It is hypothesised that TOD will help to reduce transport congestion in urban areas over traditional developments. This hypothesis needs to be tested by comparing TODs in practice with other non TOD areas. Residents travel characteristics such as mode share and trip length are important aspects of sustainable transport so this paper looks at these characteristics of TOD & non TOD areas. In the past some studies have gathered travel characteristics of TOD users and assessed the performance of TODs. Some of the reported benefits of a TOD were short commuting distances among the residents of a mixed – use neighbourhood because of the presence of nearby commercial land uses (Cervero, 1996), decrease in automobile ownership by 31 percent as land uses changed from homogeneous to diverse, and walking and public transit as more suitable alternatives than private vehicle use due to mixed land uses (Cervero, 1996; Hess and Ong, 2002).

Cervero and Gorham (1995) compared commuting characteristics of transit-oriented and auto-oriented suburban neighbourhoods, in the San Francisco Bay Area and in Southern California. The

relationship between neighbourhood type, transit mode shares and generation rates was studied using regression models. McCormack et al. (2001) empirically explored the transport impacts of mixed land use neighbourhoods using a two day travel diary data collected over three neighbourhoods of the greater Seattle, Washington area by comparing household location and commercial establishment, trip stops, transit, pedestrian trips, number of trips, travel time, travel speed, and travel and socioeconomic characteristics. This data set was then compared with countrywide identical household travel data. The ANOVA statistical technique was used to demonstrate the variations in travel measures with household or socioeconomic categories.

Deakin et al. (2004) presented the multiple roles of parking management and efficacy of TOD in smaller cities by conducting surveys for workers, shoppers, and residents in downtown Berkeley, California (part of the greater Bay Area) which focused on land use, parking supply and use, mode choices, and housing and jobs development. An international comparative analysis of relationships between car ownership, daily travel and urban form using travel diary data from the US and Great Britain (GB) was conducted by Giuliano and Dargay (2006). Car ownership at the household level was represented by a discrete variable and modelled using ordered probit specification. Lund (2006) reported the results of a survey of households (605 people) who moved to TODs within the past 5 years in the San Francisco Bay Area, Los Angeles or San Diego, and studied the factors that led these households to move to TODs and its implications on transit use. Binary logistic regression analysis was used to predict the probability that a survey respondent cited a particular factor as one of their household's top three reasons for choosing to live in a TOD.

Generally, the results from past studies indicated the efficiency of a TOD in terms of transport. McCormack et al. (2001) found that the residents of a TOD travel fewer kilometres as compared to its counterparts but there was not much advantage when travel times were considered. A lower car ownership rate was observed by Deakin et al. (2004) and Giuliano and Dargay (2006). As a result of this, there was less drive alone trips and an increase in walking and cycling trips and trip rates (Cervero and Gorham, 1995). Access to transit was one of the reasons for residents to live in a TOD which indicated very high probability of using transit (Lund, 2006).

In summary, few studies were found assessing the efficacy of a TOD in practice, so more evidence needs to be gathered. Although some work has been done addressing the various issues related TOD development (Allan, 2011; James, 2005 and Mephram, 2005), there was no significant research undertaken considering TODs evaluation from an Australian perspective. To address this issue, a detailed comparison was required to test the transport efficiency of TODs. So this paper presents a comparison by considering a fully planned development located in Brisbane, Australia with the household travel survey data (SEQTS, 2009).

2. Objective

The main objective of this paper is to assess the efficacy of a TOD by comparing the characteristics of residents of a case study TOD with that of characteristics of residents living in non TOD suburbs in the same urban area. This will be achieved by undertaking a regional comparison and a suburban comparison. The comparative analysis will be mainly conducted using household characteristics such as average household size, vehicle ownership and travel characteristics such as mode shares and trip lengths of residents of TOD and non TOD areas. A case study TOD located in Brisbane, Australia was selected to collect the travel data. The detailed approach for this study is given in the following section.

3. Approach

To perform the comparative analysis, residents' travel data from the case study TOD was needed. For this purpose, Kelvin Grove Urban Village (KGUV), a fully planned mixed use development spanning over 16.57 Ha located in Brisbane, Australia, was used as the case study TOD. The mixed uses at this development consist of residential, commercial, office, education and recreational land uses. The main aspect considered for study site selection was the transportation facilities and proximity to the Brisbane CBD. The site is well connected to arterial roads and has an internal street network forming a grid pattern, with parks and open spaces promoting walking and cycling. KGUV does not have a major transit station at its centre; instead major public transport corridors run along east and west flank with an intercampus shuttle bus service running through its heart. KGUV is served by two Bus Rapid Transit (BRT) stations on the Inner Northern Busway (INB) and two express bus stops on a parallel arterial, which are serviced by nine express bus services and seven local bus services. FIGURE 1 shows an aerial overview of KGUV with the transit corridor details. The analysis for transit availability was conducted to determine the quality of transit service using the formal framework stated in Transit Capacity and Quality of Service Manual (Kittelson & Associates, 2003). The analysis indicated that KGUV has overall good quality of public transport service (For further information about calculations of quality of service, please refer Muley et al. (2007)) so the study site was confirmed as case study TOD for evaluation.

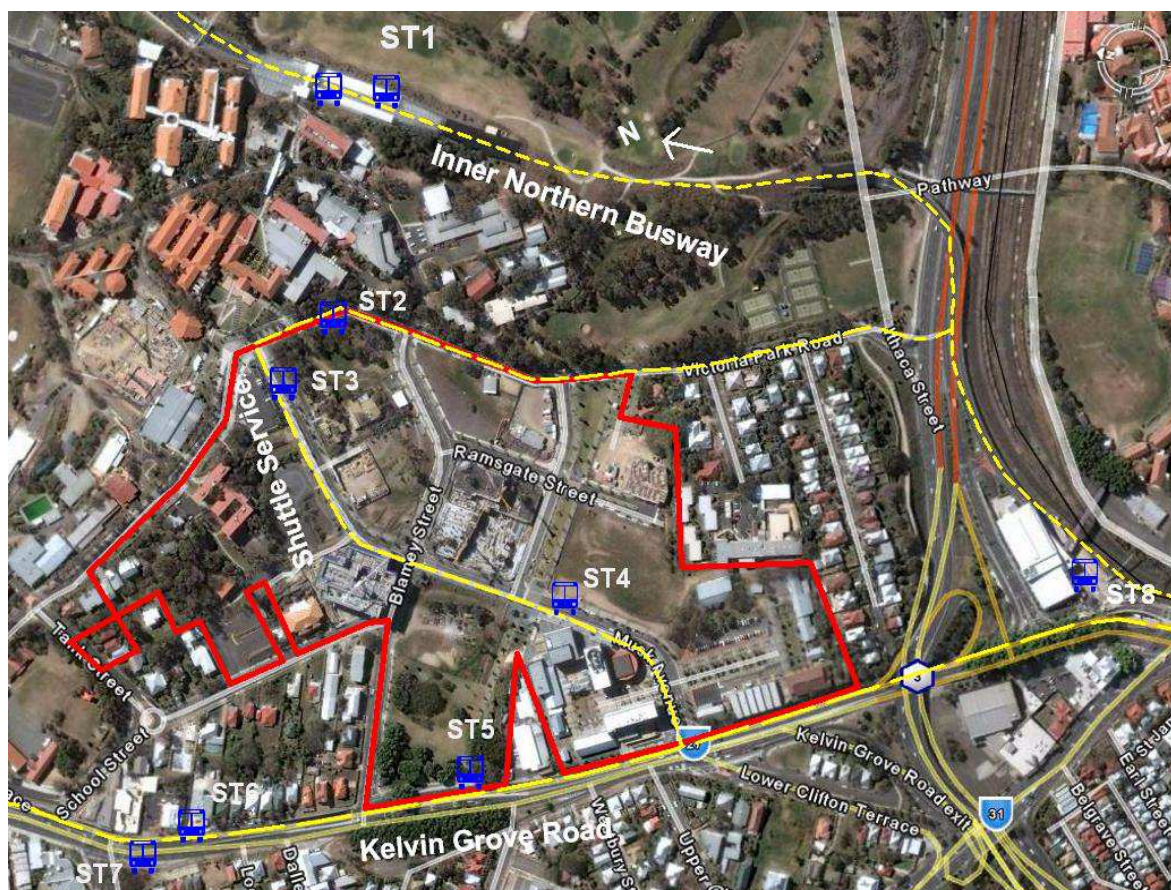


FIGURE 1. Overview of Kelvin Grove Urban Village (KGUV)

Two groups reside at KGUV; non student residents (NSRs) and student residents (SRs). A mail back survey was conducted to gather NSRs' travel data during August and September 2008 and an intercept survey was carried out during March 2009 to collect SRs' travel data. The respondents were asked to

complete a travel diary for a typical weekday (Tuesday or Wednesday) along with the household information. A response rate of 11 percent and 8 percent was obtained from SRs' and NSRs' travel surveys respectively. In total, 85 complete travel diaries were used for analysis. This travel data was compiled and analysed using Microsoft Excel® spreadsheets to acquire the household characteristics and travel characteristics. The results from the analysis were then compared with the results from the Brisbane travel characteristics.

Initially, the travel data for Brisbane residents was obtained from the South East Queensland Travel Survey (SEQTS) conducted during 2006-08. Specifically, the SEQTS survey for Brisbane statistical division undertaken in 2006; known as BSEQTS06 was used for analysis in this paper. The BSEQTS06 collected travel data and household data using a self-completion questionnaire which was hand-delivered to, and hand-collected from, the survey households (SEQTS, 2008). The BSEQTS06 obtained 4178 travel diaries from 1564 households and this data was analysed using Microsoft Access®. The household characteristics and travel characteristics of KGUV residents were compared with that of the residents of Brisbane as a whole (known as the Brisbane Statistical Division (BSD), Brisbane's Inner North Suburbs (BINS) and Brisbane's Inner South Suburbs (BISS). BINS and BISS are typical cases of suburbs located within close vicinity of an Australian capital city CBD. Note that BISS travellers often need to cross the Brisbane River, which has a limited number of crossings or bridges and is a natural barrier. The household characteristics and travel characteristics for KGUV residents are presented in the next section, followed by the results of the comparative analysis.

4. Characteristics of KGUV residents

4.1. Household characteristics

The KGUV residents were broadly divided into NSRs who live in apartments, and SRs who live in student accommodation. The apartments at KGUV were typically one or two bedroom while the students were living in shared units having 1 to 6 bedrooms. FIGURE 2 shows the variation in the number of bedrooms in a household for KGUV residents'. The variation in the household size is displayed in FIGURE 3. There was a drop in one person households compared to the number of bedrooms. This was largely because of a couple or family of two persons living in a one bedroom apartment.

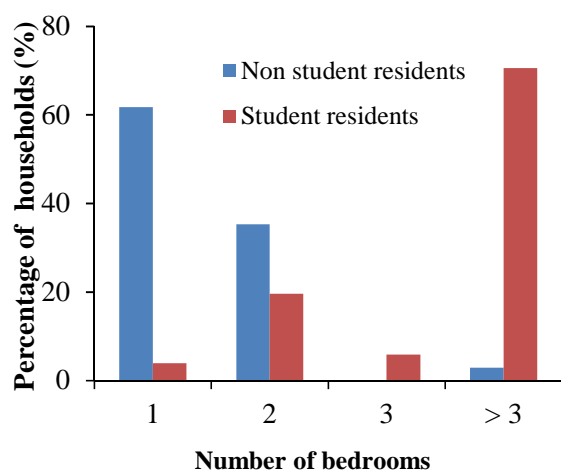


FIGURE 2. Distribution of number of bedrooms at residents' households

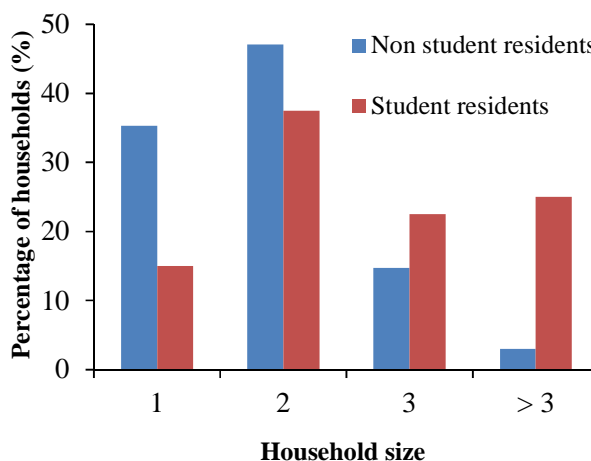


FIGURE 3. Distribution of household size at residents' households

Vehicle ownership is an important household characteristic describing private vehicle dependency of residents. The distribution of vehicle ownership for KGUV residents is given in TABLE 1. KGUV residents had lower car ownership compared to a high driver's licence possession. Around one fifth of households did not have a car. A large proportion of KGUV households did not possess either a bicycle or a motorcycle, indicating very low vehicle ownership, which can result in low private vehicle usage. During the interviews, some of the respondents pointed out that they did not have a car or bicycle because they did not need it. Most of the student residents left their car at home. They believed that attractions were sufficiently close to each other that they did not require a vehicle for transport. This is argued by many transport professionals to be one of the biggest advantages of TODs.

TABLE 1. Vehicle ownership at residents' households

Parameter	Quantity	Non student residents	Student residents
Cars	0	20.6	41.2
	1	55.9	47.1
	2	20.6	7.8
	>= 3	2.9	3.9
Bicycles	0	82.4	88.2
	1	14.7	9.8
	2	2.9	2.0
Motorcycles	0	100.0	98.0
	1	–	2.0
Valid driver's licence holders	0	5.9	7.0
	1	52.9	14.0
	2	38.2	34.9
	3	–	20.9
	> 3	2.9	23.3

Note: All values are presented in percentage

4.2. Trip characteristics

In the case of non student residents only one person did not travel on the assigned travel day, while in case of student residents three students did not travel on the assigned travel day. A retired person who did not travel on the assigned day mostly travelled on the pension day and sometimes for visiting a doctor. The students did not travel because they did not have any academic engagements on that day. A set of 34 and 51 travel diaries were analysed for non student residents and student residents respectively.

TABLE 2 lists the minimum, average and maximum number of trips made by the residents at KGUV. The minimum number of trips was 0 as the respondents did not perform any trip on the assigned travel day. A non student resident made more trips than a student resident, partly because of the various activities required to perform by a household (pick up and drop off formed a major share of this). On a typical weekday, the residents mostly travelled for work or education during the day and in addition to a return trip home for shopping or recreation during the evening. The evening shopping and recreation trip was mostly on foot due to closely located attractions.

TABLE 2 Number of trips for residents at KGUV

Description	Number of trips per person		
	Minimum	Average	Maximum
Non student residents	0.0	2.9	6.0
Student residents	0.0	2.4	4.0

4.3. Residents' mode share

Mode share was determined for all trips undertaken by residents on a typical weekday. The travel mode share for residents living in apartments at KGUV is shown in FIGURE 4. The NSRs at KGUV typically travelled by either car, public transport or walk only. No train, ferry or bicycle trips were reported; the reason for no train or ferry trips was that KGUV does not have a train station or a ferry terminal within easily walkable distance. The mode shares indicated that 49 percent of the residents travelled by the more sustainable modes of transport. Almost 50 percent (49.5 percent) of the residents had another mode choice for performing this trip.

FIGURE 5 shows a pie chart showing the distribution of mode shares for the students living in student accommodation for all trips on a typical weekday. It can be noted that these residents travelled by only three modes of transport; car, walk only and public transport (specifically public bus and train no ferry trips were reported) similar to non student residents. No resident used a bicycle or taxi for arriving at their desired destination. The reason for there being no bicycle trips is postulated to be due to the limited bicycle connections available to more remote areas, heavy traffic around the area, and the hilly terrain of the area.

Public transport and walk only were equally preferred modes by student residents with a share of 46 percent each. Most of the residents (More than 90 percent) used the modes of transport labelled as sustainable (which include walk only and public transport) and only eight percent residents' used car as their mode of transport. When asked about mode choices, around 78 percent of residents did not perceive that they had any choice other than their chosen mode of transport; we therefore consider them to be captive users.

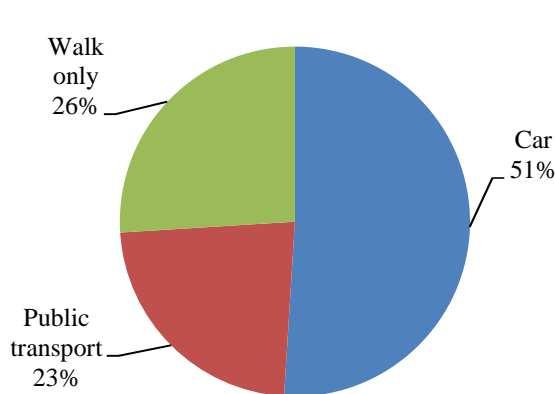


FIGURE 4. Mode share for Non Student residents

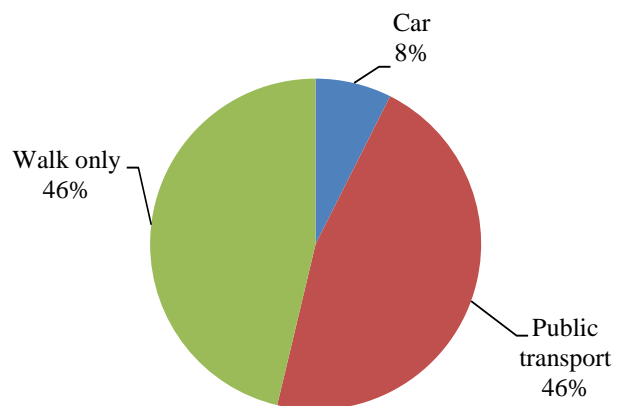


FIGURE 5. Mode share for resident students

4.4. Trip length

The minimum, average and maximum trip lengths by mode of transport for residents at KGUV were calculated for all the trips listed in the travel diary. The details are listed in TABLE 3 and TABLE 4 for non student residents and student residents respectively. Theoretically, the minimum trip length was zero. This is an internal trip undertaken by a student to the university or a shopping trip undertaken by walking. For non student residents, the maximum trip length was observed as 94.4km for a non student resident by car and the overall average trip length was 4.9km. Similarly, the maximum trip length for student residents was observed by public transport (train) as 83.8km and overall average trip length was 4.2km. The overall average trip lengths indicate that the trips originating from KGUV were distributed to a relatively smaller

area specifically for student residents. The residents used car for accessing destinations located away from KGUV. This also points out that the mixed uses can help in containing the trips over a smaller area.

TABLE 3 Trip lengths by mode of transport for non student residents at KGUV

Mode of transport	Trip lengths (km)		
	Minimum	Average	Maximum
Car	0.9	7.5	94.4
Public transport	2.9	3.8	8.6
Walk only	0.0	0.4	3.1
Combined (overall)	0.0	4.9	94.4

TABLE 4 Trip lengths by mode of transport for student residents at KGUV

Mode of transport	Trip lengths (km)		
	Minimum	Average	Maximum
Car	2.2	14.7	41.1
Public transport	2.1	6.6	83.8
Walk only	0.0	0.2	2.4
Combined (overall)	0.0	4.2	83.8

5. Comparative Analysis

This section presents a comparison of KGUV residents' characteristics with that of the residents of BSD, BINS and BISS. It should be noted that household characteristics of KGUV student residents were not included in the analysis as it is argued that the characteristic of students' accommodation are different than of typical conventional households due to difference in demographic characteristics. So in order to obtain a fair comparison, the data for this user group was not included. However, this data set was used for other comparative analysis.

5.1. Comparison of household characteristics

TABLE 5 represents a comparison of KGUV residents' household characteristics with the residents of BSD, BINS and BISS. The comparison of household size suggests that KGUV residents have slightly lower household size than residents of BINS and BISS and considerably smaller household size than BSD households. This is likely due to the higher number of single and double bedroom apartments at KGUV.

KGUV has a lesser average number of bedrooms per household, indicating these apartments are highly attractive to small family households; typically to young adults and families with no children. However, a TOD should also cater for large families as they tend to drive more for children's activities, and living in such an environment may help to reduce the number of vehicle trips by a household considerably.

TABLE 5 Comparison of residents' household characteristics

Household characteristics	KGUV	Brisbane statistical division	Brisbane inner north suburbs	Brisbane inner south suburbs
Average household size	2.0	3.4	2.3	2.2
Average of number of bedrooms	1.4	3.5	2.8	2.5
Average motor vehicles per household	1.1	2.0	1.5	1.3
Average bicycles per household	0.2	1.8	1.2	1.0

Note: These are Non Student Residents' (NSRs) characteristics only

Transport professionals often postulate that TOD residents have low vehicle ownership; this is true in case of KGUV, with 1.1 vehicles per household in comparison to 2.0, 1.5, and 1.3 vehicles per household for BSD, BINS and BISS respectively. This finding was similar to the findings of previous studies (Deakin et al., 2004 and Giuliano and Dargay, 2006). When asked about vehicle ownership while conducting the surveys; the respondents indicated that they do not own a car because they do not need one. One respondent said, “Everything is so close here. I can access everything by walk and I like it very much”. The low vehicle ownership requires less parking infrastructure, and as such this aspect of TOD needs to be studied separately for appropriate parking arrangements, as does making these developments more pedestrian friendly.

Transport professionals also often postulate that TOD residents have higher walking and cycling trip rates, which means that they ought to have higher bicycle ownership. However, KGUV residents exhibit an opposite trend, having only 0.2 bicycles per household in comparison to 1.8, 1.2 and 1.0 bicycles per household by BSD, BINS and BISS households. This may be attributable to the reasons cited earlier.

5.2. *Comparison of trip characteristics*

When the average trip characteristics for KGUV residents and BSD, BINS and BISS residents were compared (TABLE 6), it was found that on an average KGUV residents undertook fewer trips on the given travel day (2.6 trips/person) compared to BSD (3.1 trips/person), BINS (3.6 trips/person) and BISS (3.5 trips/person) residents. The minimum trips were the same (zero) as there were few respondents in each category who did not travel on the assigned travel day. KGUV residents made a quarter and one third fewer trips when compared with BSD and BISS, and BINS residents respectively. Previous research suggested that TOD residents make fewer car trips and more walk trips. Car trips are stated to be replaced by walk trips, but making same number of trips as for residents living in conventional development (Sun et al., 1998). However KGUV residents made less number of trips exhibiting an opposite trend.

TABLE 6 Comparison of residents’ average trips per person

Description	KGUV	Brisbane statistical division	Brisbane inner north suburbs	Brisbane inner south suburbs
Minimum trips by a person	0	0	0	0
Maximum trips by a person	6	23	18	23
Average trips per person	2.6	3.1	3.6	3.5

5.3. *Mode share comparison*

The mode shares for residents’ trips on a weekday were compared to each other. TABLE 7 lists the details of mode shares for KGUV, BSD, BINS and BISS residents. Only 27.6 percent of KGUV residents used the car, compared to around 75 percent for other inner suburban residents. KGUV residents used public transport more than thrice and four fold the rate compared to other inner suburban residents and BSD residents respectively. Similarly, KGUV residents walked more than three times the rate compared to other inner suburban residents. A small proportion of BSD, BINS and BISS residents used bicycle for their travel while none of the KGUV resident used bicycle. Noteworthy, taxi was not a popular mode of travel in any group of residents.

Overall, 72.4 percent of KGUV residents used sustainable modes of transport for making their first trip of the day. On the other hand, only 17.4 percent, 22.2 percent and 24.4 percent residents of BSD, BINS and BISS used such modes for their travel respectively. The relatively high mode share for KGUV residents was due to the fact that many residents were living in KGUV and working / studying not too far from their place of residence. Further, they have high quality public transport facilities close by and services to / from various destinations. This outcome was in line with the previous findings from past

studies (Cervero and Gorham, 1995; Cervero, 1996; and Hess and Ong, 2002). This demonstrates that KGUV has a greater tendency towards using modes of transport labelled as sustainable; supporting the hypothesis that TOD development will help to reduce transport congestion in urban areas over traditional developments.

TABLE 7 Mode share comparison for residents' trips on a weekday

Mode of transport	KGUV	Brisbane statistical division	Brisbane inner north suburbs	Brisbane inner south suburbs
Public transport	35.7	7.8	11.6	10.9
Walk only	36.7	8.5	9.9	11.1
Bicycle	0.0	1.1	0.7	2.4
Subtotal labelled as "sustainable"	72.4	17.4	22.2	24.4
Car	27.6	81.6	75.8	72.5
Taxi	0.0	0.3	1.2	1.1
Other	0.0	0.7	0.8	2.0

Note: Mode share values are in percentage

5.4. Trip length comparison

When the average trip lengths for KGUV, BSD, BINS and BISS residents' trips were compared (Table 8), it was found that overall KGUV residents travelled within close vicinity as compared to BSD, BINS and BISS residents. The reduction in average trip length for residents shows that the TOD residents travel fewer kilometres, this was similar to the finding determined by McCormack et al. (2001). The average trip length by public transport for KGUV residents was one third and slightly lower than corresponding trip lengths for BSD, and BINS and BISS residents respectively. Similarly, the residents at KGUV had very short (about one third) walking trips (0.3km) compared to BSD (0.9km), BINS (0.9km), and BISS (0.8km) residents. The residents of BINS had lower bicycle average trip length than BSD and BISS residents possibly due to the hilly conditions noted before. The average trip lengths by car suggests a similar value for KGUV and BINS residents, this was slightly lower than BSD residents' and higher than BISS residents' average car trip lengths. The higher trip length for car trips was in contradiction to the claim of TOD residents' shorter car trips made by (Sun et al., 1998 and Steiner, 1998). It should be noted that local factors will specifically impact the trip lengths.

Table 8 Comparison of average trip lengths for residents' trips on a weekday

Mode of transport	KGUV	Brisbane statistical division	Brisbane inner north suburbs	Brisbane inner south suburbs
Public transport	5.8	16.5	7.0	8.4
Walk only	0.3	0.9	0.9	0.8
Bicycle	–	4.1	2.5	4.1
Car	8.5	10.4	9.4	6.9
Taxi	–	8.0	7.9	4.7
Other	–	7.1	4.5	1.5
Overall	4.5	10.0	8.2	6.2

Note: Average trip lengths are in km

6. Conclusions

The results of a comparative analysis indicated that TODs are transport efficient in practice when compared with the other non TOD areas. The NSRs of KGUV had one or two person households while the SRs were living in a shared unit which increased the household size of KGUV residents. The comparison with the residents of BSD, BINS and BISS showed that KGUV residents had lower household size. On an average, KGUV residents made fewer trips than BSD, BISS and BINS residents. Due to presence of mixed land uses the KGUV residents possessed fewer motor vehicles (1.1) per household in

comparison to its other counterparts (BSD at 2.0, BINS at 1.5 and BISS at 1.3). This reduces the dependence on motor vehicle and ultimately restrains its usage.

The mode share comparison showed that there were only 27.6 percent car trips as opposite to 75.8 percent, 72.5 percent and 81.6 percent car trips by BINS, BISS and BSD residents respectively. Although KGUV residents used only few modes of transport, the proportion of sustainable modes was very high which resulted in more environment friendly practices. This outcome provides evidence to support the presumption that TOD is a more sustainable form of development than traditional development, with respect to travel modes of residents. This high proportion of sustainable mode usage resulted in more environment friendly practices supporting transportation claims of TODs and making them more transportation efficient. A good public transport connection to or from various destinations at KGUV attracted higher public transport mode shares and subsequently reduced car usage. Clustering of activities was correlated with more walking trips; specifically for shopping and recreational trips.

The comparison of overall average trip length for KGUV, BSD, BINS and BISS residents indicated that KGUV residents have lower average trip lengths as compared to its counterparts. When the average trip lengths by car and public transport were compared for all trips undertaken by residents, it was found that KGUV and BINS used car for travelling farther and used public transport for accessing destinations located closer to their residence. This may be because of availability of good public transport service to the destinations located closer to their homes and strict parking conditions in those areas. On the contrary, the residents of BSD and BISS exhibited an opposite trend than KGUV and BINS residents. This might be possibly due to the similar factors as of KGUV and BINS residents but exhibiting an opposite trend.

These results provide a means of comparing transport performance of KGUV with respect to non TOD conventional developments, indicating the travel impacts of one kind of TOD. The outcomes from this comparative analysis should, however, be applied with caution while planning future TODs, as each TOD has its own location, geographic, demographic, socio-economic and built form characteristics. No two TODs are exactly alike. The finding that sustainable travel choices are made at this site, however, supports the notion of development of future TODs from KGUV users' perspective.

7. Future directions

In continuation of this research, the demographic characteristics of residents also need to be examined and compared. In addition to the travel modes and trip lengths, other travel characteristics such as travel times, and access and egress times and trip making characteristics need to be compared on a similar basis to gain an overall picture of TOD transport efficiency. Although this study supports TOD planning, travel data for more case studies at various scales and characteristics should be examined. In the Australian context, this task will become easier as more TODs are developed and able to be studied by transport researchers.

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