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Evaluating Access to Public Transport throughout Alternate Access Periods

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Abstract

This research was undertaken to examine how the measurement of access to public transport changes with the use of different methods to calculate access. It also aimed to compare the access to transport across different times of the day. The aim is to develop a measure to evaluate access to public transport and to make several comparisons: between estimates obtained via different methods and between different times of a day. The methods used in the analysis are the Euclidean Buffer and the Network method. The Euclidean Buffer plots a 400m buffer around each of the transport stops and calculates the number of people within the buffer, while the Network method plots a 400m walking path which approximates the pedestrian's path to the transit station. The public transport network of the Brisbane city is used as a case study. The result of the research proposes that using the Euclidean Buffer Method gives 84.3% coverage for the network whereas the Network method has coverage of 67.8%. Results for the different times shows that there is a negligible difference in access from peak to off-peak and even on Weekends. However, the access considerably reduces in the late night and after mid-night hours.

1. Introduction

Access has been one of the most important factors in design and evaluation of public transport networks and one of the keys to attract passengers to this mode (Murray, 2001). No need to mention that using public transport leads to a reduced congestion, less emissions, and a more active lifestyle. Therefore, an increase in its mode share has been targeted by many road authorities. In South East Queensland (SEQ), the target is to double the share of public transport by 2031 (DTMR, 2010).

Access is defined in different ways in the literature. In principle, access can be defined as the "ease of reaching goods, services, activities, and destinations" (Litman, 2012). More specifically, the convenience or difficulty of getting from an origin to a destination in a public transport network was used as access (or accessibility) (Currie, 2004, Zhu and Liu, 2004). However, there is no consensus on one measure or a unique calculation method for access.

An insight into the effect of a calculation method for access would impact a more precise definition of the future policies. An example was the target policy in SEQ to have 90% of the population within 400 m of a public transport stop by 2022 (DTMR, 1997). To evaluate the progress of this goal, a method needs to be devised to evaluate access to public transport stops with the addition of analysis for different time periods. This study will evaluate two methods to measure access to public transport namely, Euclidean Buffer and Network methods.

Another important factor is the temporal variability of access within a day and from one day to another (e.g. from working days to weekends). Not having access to public transport at certain times of the day or on weekends, forces potential passengers to purchase a private vehicle which in turn reduces the possibility of using public transport even when public transport is available. This study will also look at the temporal variation of access to public transport.

This paper will use the case study of Brisbane, Australia which is one of the country's largest and fastest-growing cities (ABS, 2012). In the period from 2001 to 2011, the population of Brisbane city increased from approximately 0.9 to 1.1 million people. This is an approximate rise of 200,000 people and is expected to increase to 1.25 million in 2026 assuming a medium projection (ABS, 2012). This growth in population will induce additional demand on an already stressed public transport system. Public transport within Brisbane (coordinated by Translink) has a major share of the mode of transport used, where public transport carries 45% of trips to the CBD as well as to the inner northern suburbs (BCC, 2008). However, the overall share of public transport is around 7 precent of trips (DTMR, 2010). At present, the Translink network in SEQ contains over 250 bus routes and has over 25km of busway and over 400 km of rail (Translink, 2012). It carries over 330,000 people a day and has a total number of 180 million trips a year (Translink, 2012).

The rest of this paper is structured as follows. In the next section, the related literature on access to public transport is reviewed. Then, the Euclidean Buffer method and the Parcel Network method are discussed and compared. Section four presents the results of method applications at different time periods and explains the possible causes underlying the observations. Finally, the paper concludes by summarizing the key findings.

2. Research Background

There have been many studies that aimed to measure public transport accessibility and these have presented two key options for evaluation methods. Firstly there is locational access, which only calculates proximity to the transit stop. The second option includes the transit routes or frequency of the service.

The Euclidean Buffer method is an example of a locational access method. (see e.g. Cheng and Agrawal, 2010, Murray et al., 1998) Murray et al. (1998) used an Euclidean Buffer method where if any parcels of land are within a specified radius they are deemed to be accessible to that transit stop location. The radius of the buffer most commonly used in transit research in order to delimitate service areas, is a walking distance of 400m, which is a comfortable 5 minute walk for the commuter (Hsiao et al., 1997, Murray, 2001, Gutierrez and Garcia-Palomares, 2008, Zhao et al., 2003). Alternatives such as a buffer around a corridor or a diamond shape instead of a circle are also investigated (Cheng and Agrawal, 2010).

Another method used to evaluate access to public transport is to measure the walking distance following the pedestrian paths (Gutierrez and Garcia-Palomares, 2008). Although the Euclidean Buffer method is widely used in transportation planning due to its simplicity and ease of calculation (Gutierrez and Garcia-Palomares, 2008), the travel distance from the commuters' parcel of land could be longer than the 400m to reach the transit stop; even if they reside within the 400m buffer as calculated by the buffer method. The Euclidean Buffer method results in inaccuracies due to the commuter following the street network/pedestrian paths and not a straight line to access public transport. The network distance method (Gutierrez and Garcia-Palomares, 2008) consisted of mapping the pedestrian's path on the network to within a specific distance from the location of the station/stop. The parcels of land that connected with it in the set network distance are deemed accessible to that transit stop. Similarly, Biba (2010) used a parcel Network method to estimate the public transport accessibility. This study looked at the issues surrounding the parcel Network method, compares it to Euclidean Buffer and then conducts a case study on the Dallas Area Rapid Transit (DART) service. The parcel Network method uses cadastral boundaries and the data associated with them to estimate the population cover by the stop/station.

Having a basic access to transit stops is important, but if the network does not offer a reasonable travel time to a given destination, such a destination is not easily reachable and thus not accessible. Wu and Hine (2003) used a Public Transport Accessibility Level (PTAL) to assess accessibility to public transport. PTAL analysis included relative distance analysis and levels of service to all transport stops. The method took into consideration walking distance, service frequency and bus waiting time. Accessibility levels were assigned to each of the stops where a level between 0-5 was considered poor and greater than 25 excellent. Mesbah et al. (2012) studied the spatial and temporal access to Melbourne CBD from suburban locations on a streetcar (tram) network.

From undertaking this literature review, different locational access methods to estimate access to public transport have been identified: Euclidean Buffer, network distance, and the network parcel methods. All these methods range between a basic analyses (Euclidean Buffer Method) to in-depth detailed access analysis per parcel of land (network parcel method), and increase in complexity: the Euclidean Buffer method plots a 400m catchment disregarding pedestrian paths, while the network parcel method considers each parcel of land in its analysis. The PTAL method adds an additional view to the problem, considering accessibility from the perspective of the bus frequency and time. The measure developed in this study incorporates aspects predominantly from the Euclidean and network parcel, methods. The purpose of this paper is to discuss the process involved in creating the measure, and to evaluate access to the public transport system in Brisbane City with respect to access in different time periods such as peak, off-peak and weekends.

3. Research Methodology

The method undertaken in the research uses Geographic Information Systems (GIS) based analysis in determining access to transit stops. The data used in the analysis is taken from the Brisbane Strategic Transport Model (BSTM) for transit routes and stops. The frequency data is applied from 2012 timetables.

The population data that is used in this access model are the routes and transit stops (as sourced above); Australian Bureau of Statistics (ABS, 2011) population data as well as boundaries for the Statistical Area 1 (SA1), digital boundary cadastral data (DBCD) and road network data.

In order to analyse access to transit stops, an analysis was undertaken using two methods: The Euclidean Buffer method and the parcel Network method. Each of the methods has its advantages, which are discussed and analysed in the following sections. In addition to this, access is monitored between different access periods, and these periods are shown below in Table 1.

Table 1: Public Transport Access Time Periods

Period	**Time Interval**	
	Hours	**Days**
Peak	07:00 – 09:00; 16:00 – 18:00	Monday – Friday
Off-Peak	05:00 – 07:00; 09:00 – 16:00; 18:00 – 22:00	Monday – Friday
Weekend	06:30 – 23:00	Saturday and Sunday
Late Night	22:00 – 00:00	Monday – Friday
Nightlink	00:00 – 04:00	Friday and Saturday

3.1. Euclidean Buffer Method

The Euclidean Buffer method uses a 400m circular buffer around each bus stop to evaluate the number of people who have access. Once completed, the buffer can be intersected with individual parcels of land to establish the number of parcels selected. An example of this is shown below:

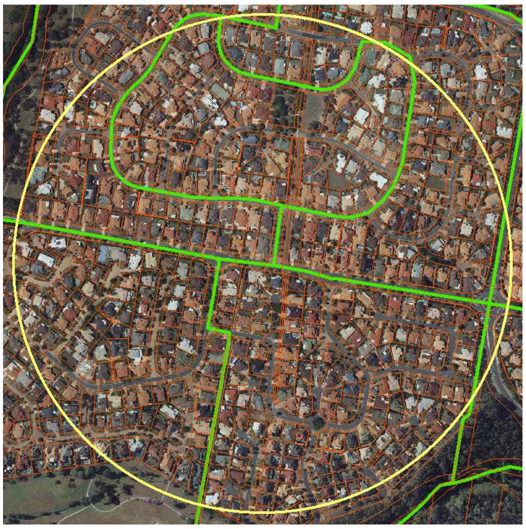

Figure 1 - SA Boundaries With 400m Buffer

Figure 2 - Selected Parcels Intersecting with 400m Buffer

3.2. Parcel Network Method

The Parcel Network method uses a 400m route distance to calculate the access to a particular stop. The 400m path follows the street paths and plots the actual walking path of the transport user to the network access point**.** Once this was completed, a buffer was used to select each of the parcels along the 400m paths. An example of this is shown below in Figures 3 and 4:

Figure 3 - SA Boundaries with 400m Network Plot

Figure 4 - Selected Parcels Intersecting with 400m Network Plot

3.3. Post Processing

Upon completion of the previous tasks, the data that contained selected parcels were output. As can be seen in the examples above, parcels were selected that were not residential land. These parcels may contain industrial land, roads and waterways, to mention a few. To eliminate these unwanted parcels, the data was sorted to remove them by the use of Land

Tenures, Parcel Indicators and Parcel Type Codes. Land Tenure, Parcel Indicator and Type are codes that are given to a parcel of land to show who owns the land right for it. In this study, two Land Tenure codes of Free Hold (FH), and Housing Land (HL) are selected. Also, a Parcel Indicator of Lots (Code 00) and Parcel Type of Lot Parcel (Code L) are included. Other codes did not have residents and thus excluded from the analysis.

The next step in the process was to calculate the number of people that are situated within the selected data area. The DBCD can have the unique SA1 digit code for each SA1 area put into the DBCD data. The ABS SA1 data that was used is the number of people living in each of the Statistical Areas and the average number of people per household. Once the number of parcels was selected this was multiplied by the average of people per household. Once this was calculated to each the Euclidean and Network methods, it was applied across the whole network and applied between different times Peak, Off Peak, Weekend, Late Night and Night link services. Following the calculation of the values, comparisons can be made between the different times as well between both of the methods.

4. Results

This section presents the findings of this study, and displays the results for each of the Euclidean Buffer and Parcel Network methods. It also presents the change of access to public transport at various times during the day via the use of diagrammatic response showing an example location of the network. Upon completion of the results they are compared to the total number of residential parcels 575,441 and the total population 1,041,839 (ABS, 2011).

4.1. Analysis of Time Periods

To calculate the number of people who have access to any particular bus stop was calculated via two methods: the Euclidean Buffer and the parcel Network method. Over the entire region of Brisbane City a comparison can be made between time periods of Table 1. The results of the analysis are shown in Table 2 below:

Table 2 - Population Coverage by Time Period

Period	**Population Coverage**		
	Euclidean Measure [% Coverage]	Network Method [% Coverage]	Difference [-]
Peak	84.2%	61.7%	22.8%
Off-Peak	83.1%	60.2%	22.5%
Weekend	78.9%	57.3%	21.6%
Late Night	46.4%	27.7%	18.6%
Nightlink	25.8%	14.3%	11.5%

As can be seen in the above table, peak hour has the most population coverage, while the late night services have the least. One of the interesting points to note is that there is little change in population coverage between the Peak, Off-Peak and weekend periods. This little change can be related to the frequency and the types of services. This could be due to the fact that most trains and ferries run all day including the Peak, off-Peak, Weekend, Late-Night and Nightlink periods. The mode that has the major influence is bus services. Table 3 shows the number of bus, Train and Ferry routes in operation across the periods.

Table 3 - Bus, Train and Ferry Operations

Period	Number of Services		
	Bus	Train	Ferry
Peak	193	125	10
Off-Peak	146	125	10
Weekend	116	125	10
Late Night	30	20	10
Nightlink	13	9	0

From the above table, the further away from the peak times a commuter travels, the more the number of bus services decreases. However, this reduction in services does not correspond to the same rate of decrease in the level of access, as shown in Figure 5:

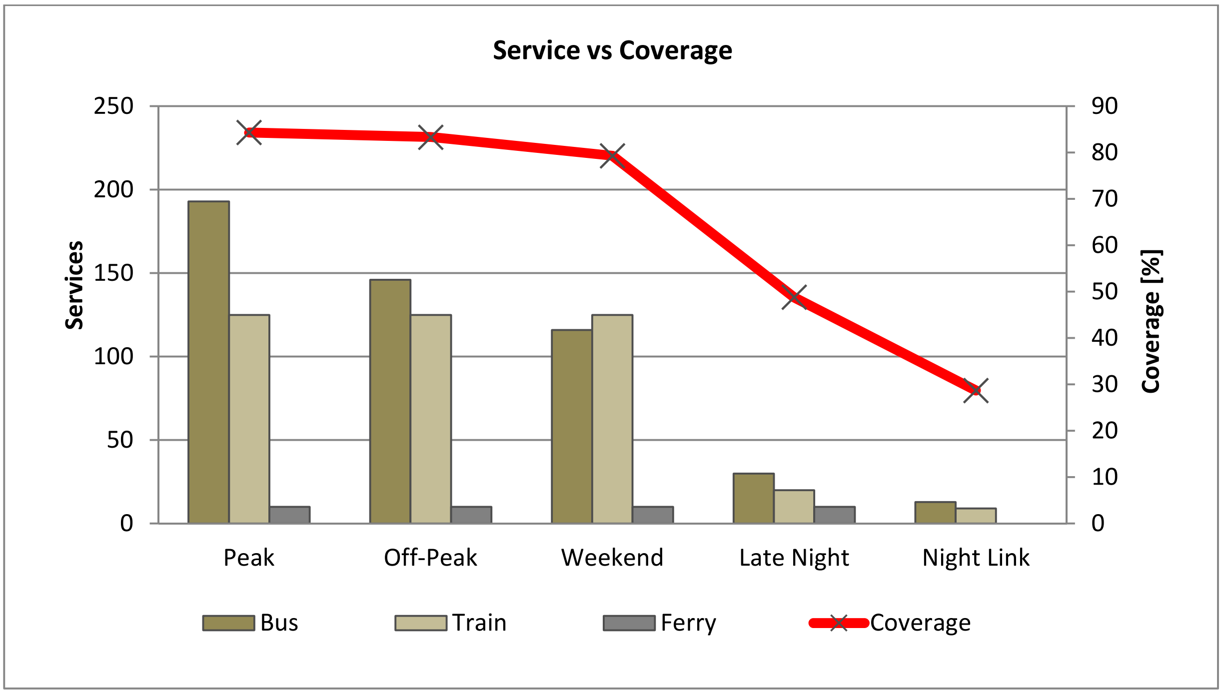

Figure 5 – Services throughout Different Periods

So why does not this correlate? The figure above shows that moving across the time periods has little effect on the access capability of the network, with the reduction of services running. This can be attributed to the operation of the network. Translink have three primary services types, and these are listed in Table 4.

Table 4 - Service Type Descriptions

Type	Description
Type 1	A high frequency express services run commonly every 15/10 minutes which service every 2/3 stops along a particular route.
Type 2	A low frequency service running at 30 or 60 minutes intervals, services every stop along the route.
Type 3	A Peak service that only runs during the peak period (07:00 – 09:00; 16:00 – 18:00), which acts as a type 1 service, and runs every 30 minutes during the peak hour.

All of the above types of services run along the same route at different intervals which give additional service but not added coverage. The only exception that influences coverage is described in the case below. Consider a set of stops on a route below:

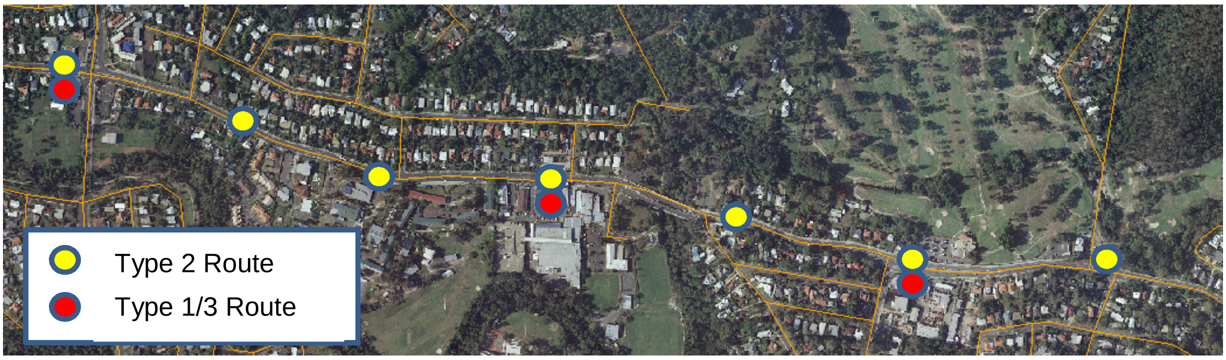

Figure 6 - Typical Route Stop Layout

On this particular route there are typically three different types of services as shown in Figure 6. Even though the frequency drops over each of the different time periods, the access measured by Euclidean Buffer and Network methods remains the same over this particular route.

There is a small decrease in access over the network between the Peak, Off-Peak and Weekend Periods. This is primarily due to the same pattern shown above being implemented over the entire network. Some routes will terminate at the end of the peak period and will reduce the coverage, which leads to the small drop in services over the entire network. This drop in coverage is typically due to the Type 3 route termination. These routes tend to fan out prior to entering the main route and then fan out again once entering the CBD.

This same pattern can be seen in the bus frequencies in Figure 7 below. It can be seen that in the peak time the average frequency over the network is approximately 22 minutes. As the time periods progress towards the off-peak and weekend time periods, the frequency of the service decreases. As seen on the above example when busses are not being run in the off peak and weekend times the overall frequency increase due to the removal of the peak hour services.

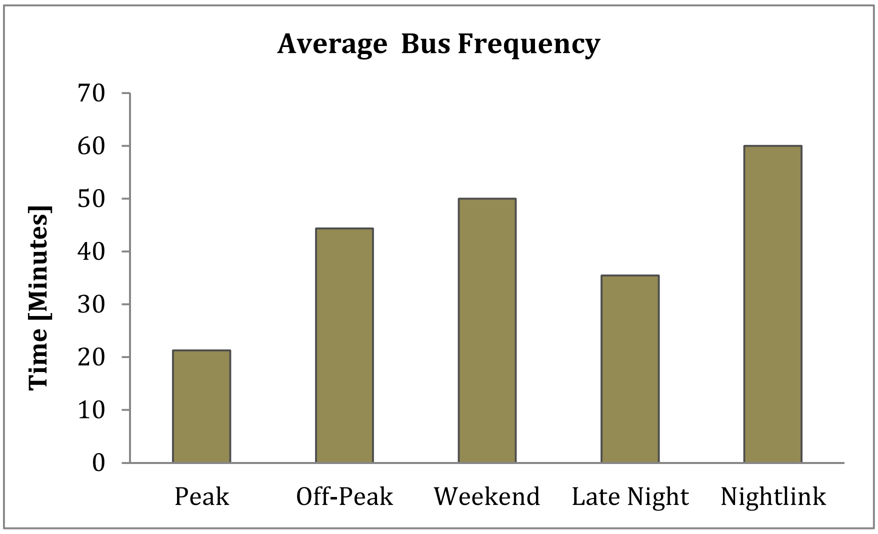

Figure 7 - Average Bus Frequency per Period

4.2. Comparison of Access Evaluation Methods

The Euclidean Buffer method is a less complicated method with which to perform a calculation, when compared to the network parcel method. However, it runs the risk of overestimating the walking distance to the transit stops. The method uses a 400 m radius circle to select the number of parcels that lie in the buffer to calculate the number of people who have access to the network, although not all parcels have an actual 400 m walking route to a stop.

Table 2 shows the difference in the methods used in this paper. As can be seen in the Table 2, there is a difference between both of the access methods. This shows the access estimated by the Euclidean Buffer method is much higher than the Network method. Also, one could note the relative difference between the time periods by each of the methods. The Peak, Off-Peak and Weekend values are all around the 21 -23% different. This shows, on a relative basis, the method of use may not particularly matter. However in setting a transport policy, the method should be identified for calculation.

One of the key distinctions between the methods is their response to different street layouts. Overestimations stated earlier are made worse due to the layout of the street network. This can be seen in the Figures 8-11. The layout of the street network affects the access across the network, as demonstrated in Tables 24 and 25. If the street network has a grid layout as in Figure 8 and 9, better access to more properties can be achieved. However, if the street network is of an irregular layout, the pedestrian path becomes longer, thus making it more difficult to achieve the 400m over some parts of the network, as depicted in Figures 10 and 11. The numerical values of land parcels within 400m distance for the example of Figures 8-11 are available in Table 5. One can easily verify that the difference is greater in an irregular layout.

This can be seen in the comparison of the methods below:

Figure 8 – Euclidean Buffer method in a Grid Layout

Figure 9 – Network Method in a Grid Layout

Figure 10 - Euclidean Buffer Method in an Irregular Layout

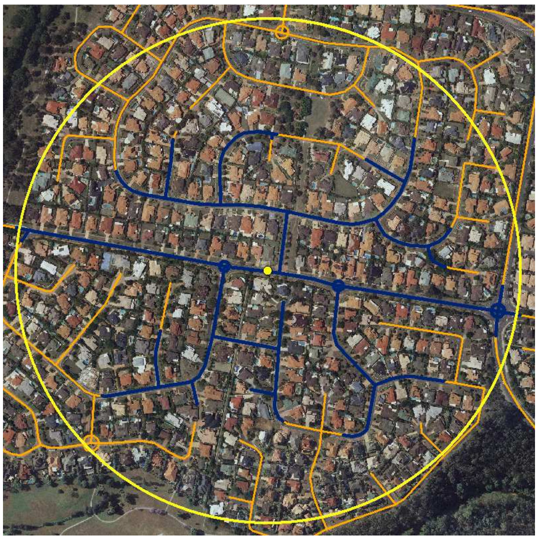

Figure 11 – Network Method in an Irregular Layout

Table 5 – Comparison of Methods in Grid and Irregular Networks

	Grid Network (Number of Parcels Selected)	Irregular Network (Number of Parcels Selected)
Network Method	359	262
Euclidean Buffer	638	451
Difference [%]	56.3 %	58.1 %

4.3. Network Method Coverage

The plot of Figure 12 shows the coverage across the entire network by the Network method during the peak time. Green represent good coverage (>70%) while red represents poor coverage (<30%) and yellow represents moderate coverage (40-60%). The grey represents areas that are primarily non-residential land use and have very few people and hence are excluded from the plot. As can be observed from Figure 12, the access improves as getting close to the Brisbane CBD in the middle of the figure. There are some areas in the outer eastern and southern suburbs with a poor coverage (red colour).

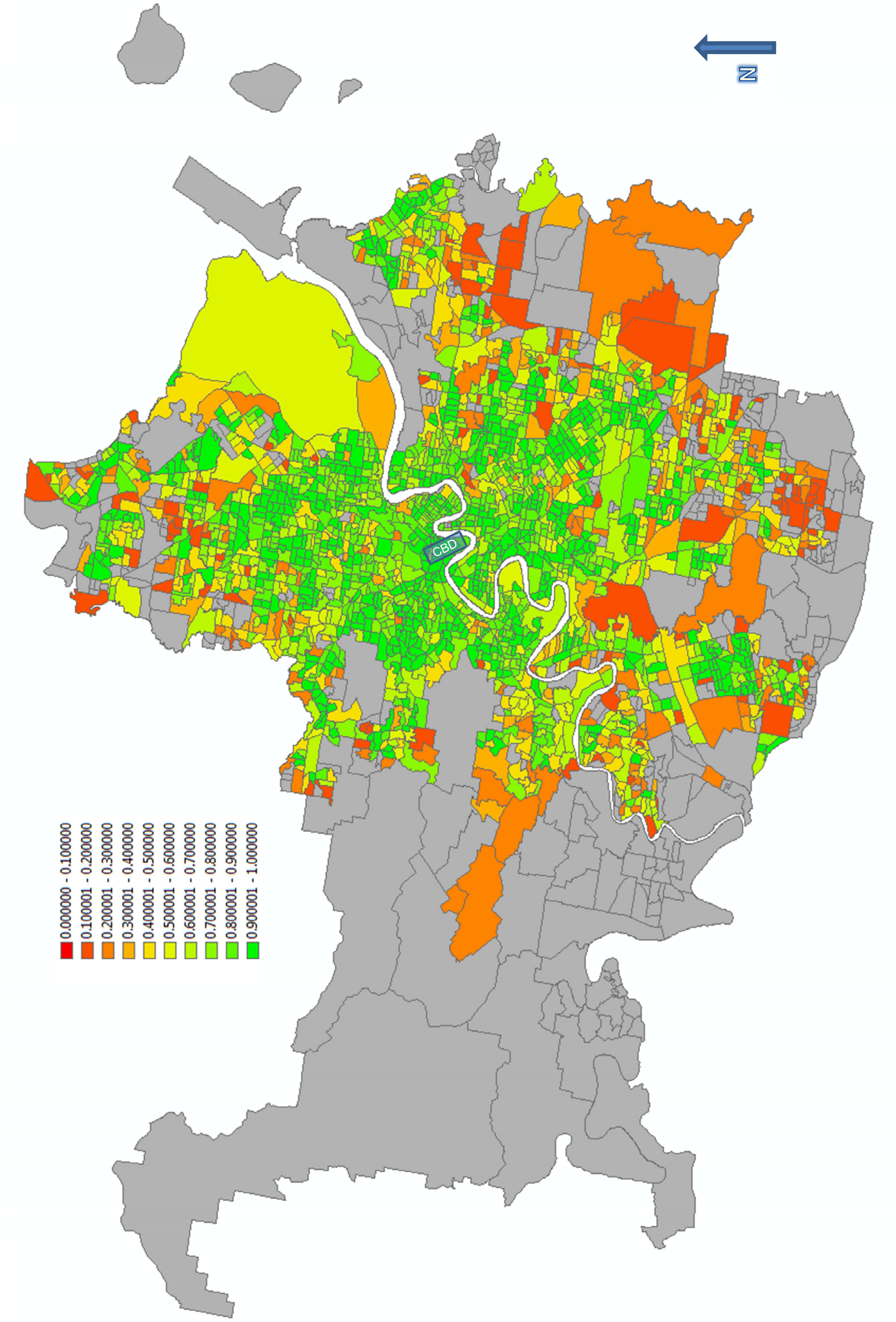

Figure 12 - Network Method Access during Peak Period

5. Conclusions

The future development of transit systems within Brisbane City is critical to ensure sustainability and to reduce road based congestion. This paper demonstrates the differences in access at different times of a day as well as the differences between two analytical methods of measuring access: Euclidean Buffer method and Network method.

The temporal variation of demand based on both of these analytical methods is investigated during peak, off-peak, weekend, late night, and Nightlink times. The coverage gradually decreased from the peak hour to off-peak and weekend periods. Nevertheless, the difference in coverage between peak, off-Peak and weekend times was approximately 3%. During the late night and Nightlink service times, the overall access was considerably less.

This paper also compared the relative difference between the Euclidean Buffer and the Network methods. The public transport coverage based on the Euclidean Buffer and Network method in the peak hour was 84.2% and 61.7%, respectively. During Peak, Off-Peak, weekend and Late Night the relative difference remain approximately the same at 16% while during the Nightlink services the difference between the methods was 12% (see Table 2).

Additionally, the performance of the two methods depends on the network layout. If the street network had a regular grid layout the Network method supplied a better coverage when compared to irregular street layout.

The change in access over the network is clear, with the predominate amount of coverage located towards the CBD region. Continuing out of the CBD there are primary corridors in which there is a high level of access to Type 1 and 2 services. In the secondary corridors, which have less access than the primary corridors, there are only Type 2 services. These can be seen on the layout plots of Figure 12 for the peak period.

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