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Time Cost Measurement of Travel in Sydney and Implications for Public Transport Patronage Potential

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Abstract

This paper reports on findings from a study of which the central research aim was to understand the spatial characteristics of linked trips initiated from three dissimilar areas of Sydney, and to measure the times and costs of these trips by mode. Travel desire was graphically shown to be almost a uniform pattern of linked movement in all directions from the home, almost regardless of where in Sydney the home was located.

The transport services were examined to establish just how well public transport was capable of satisfying this revealed demand. The three study areas were well serviced by public transport. Despite coverage of the study areas being fairly complete, the availability, frequency and coverage of service meant that they were not capable of adequately satisfying the revealed travel demand.

At present it appears that only 15% of the travel market is being pursued by public transport, compared to the 50-60% of motorised travel needs which are effectively neglected, and are satisfied only by the car. Our study suggests that the full network effect of the various public transport systems of Sydney are not being exploited because of route policy and insufficient modal integration.

The implications of these findings for the current “Cities of Cities” approach to the Metropolitan Plan are significant. There would be greater prospect of successful public transport by using more appropriate grid or mesh route structures to serve all areas, not just some areas as the current spoke and wheel structure does.

1 Introduction

Car dependency is a fact of life in Sydney, (ABS, 2008, BTS, 2010, Corpuz, 2007, Hensher, 2008) and this has significant repercussions for sustainability, equity, efficiency and health(Capon, 2007, Frumkin et al., 2004, Thompson, 2007, Baum, 2002, Zeibots, 2002, Randolph et al., 2010). However, it is something that the State government, as expressed through the Metropolitan Plan, is committed to reducing. The Federal Government, through its Infrastructure Report (Major Cities Unit, 2010) is also committed to this same goal. Why it is such an elusive objective was a motivator of this study. Also motivating the study was an interest in the debate as to the contribution of residential density and/or quality to the use of public transport (Mees, 2000, Kenworthy and Laube, 1999, Newman and Kenworthy, 1999)

The authors were given the opportunity of examining data from the Household Travel Survey collected by the Bureau of Travel Statistics that had been accurately geo coded for the origins and destinations of all trips. A detailed study was conducted using this data from three morphologically dissimilar study areas in Sydney. These areas consisted of an Inner City Urban, a Transit Suburban and a Car Based Suburban study area. This established the nature of the travel undertaken at the level of the individual trip which was predominantly short multi-staged linked trips and confirms the work of many others(Corpuz, 2007, Frank and Pivo, 1994, Hansen and Henning, 1995, Mees, 2009, Newman and Kenworthy, 1989, BTS, 2010).

With the nature of the prevalent trip types established, the time and cost implications of trips typical to those study areas were measured and compared. The time differences between using the car and public transport confirmed the work of others (Tranter and May, 2005) as being of such a large magnitude that detailed work was carried out into the reasons why public transport appeared to be so ineffective in competing with both the car and walking/cycling (the independent means of travel) for the majority of urban movement.

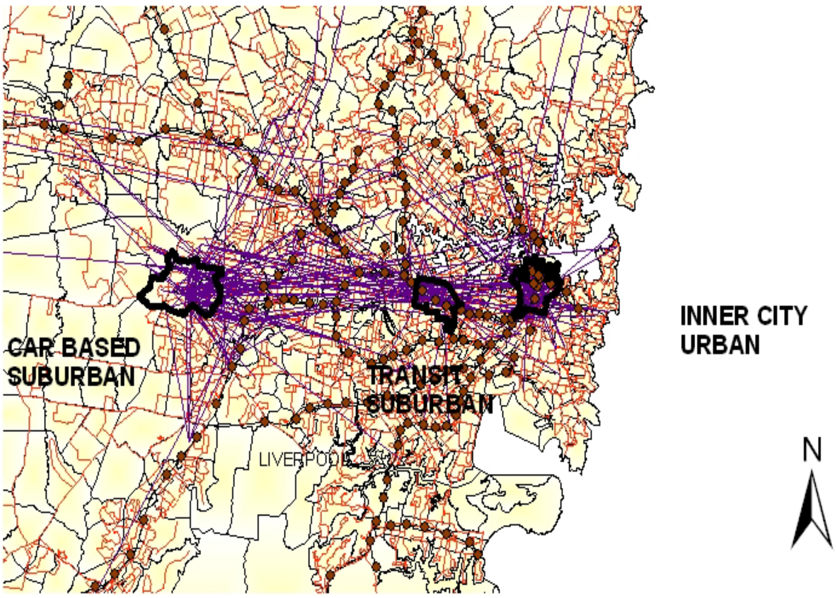
The frequency, availability, coverage and route layouts of the public transport used in the trips in the first part of the study were analysed. The routes of the public transport in particular were further analysed in a detailed measurement of simple models to represent the Branching Tree of the Sydney networks and a more disbursed distributed Mesh system that can be found in other cities. This examination suggested structural difficulties facing the existing public transport arrangements and possible directions that the Metropolitan Plan could use to address shortcomings. In particular, routing and ticketing were identified as areas that contributed to sub optimal performance. As well, support can be found for those who suggest that mixed use zoning is a substantial reason for the prevalence of walking/cycling in the inner areas (Brugmann, 2009, Frank and Pivo, 1994). There was support for those who questioned the concept of increasing residential densities around railway stations as a means of increasing use of public transport (Ellis and Parolin, 2010).

2 The Study

2.1 Study Areas

The following figure (Figure 1) shows the three study areas with the HTS trip data commencing from those areas. This is shown against a backdrop of the bus routes, in red, the train system with stations and post code boundaries.

Figure 1: Study Areas



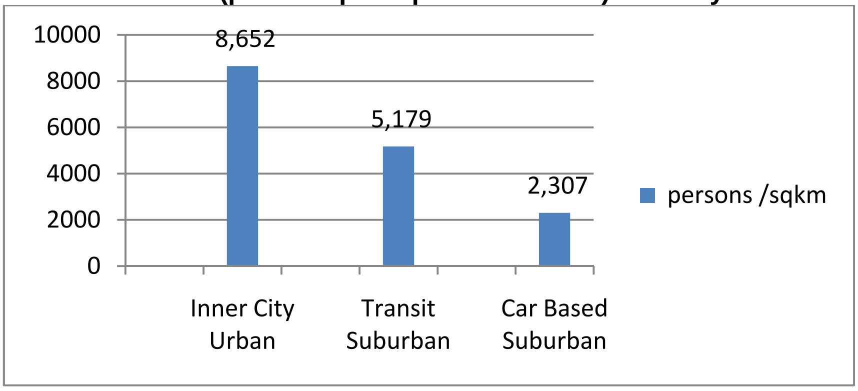
The **Inner City Urban** area is the original historic heart of the city; it generally comprises mixed use zoning and has a high residential density.

The **Transit Suburban** area comprises the suburbs developed in the early 20th Century with direct public transport access by train, segregated land use with a concentration of retail and office uses around the railway station with large amounts of separated medium residential density development.

The **Car Based Suburban** area is typical of the late 20th century low density suburb without direct access to the train. It has strictly segregated land use, well integrated accommodation of the car and very ample parking in most places.

The spread of the bus routes show that there is a good coverage of public transport to most areas of Sydney. The densities of each area are as follows:

Figure 2: Residential Densities (persons per square kilometre) of Study Areas

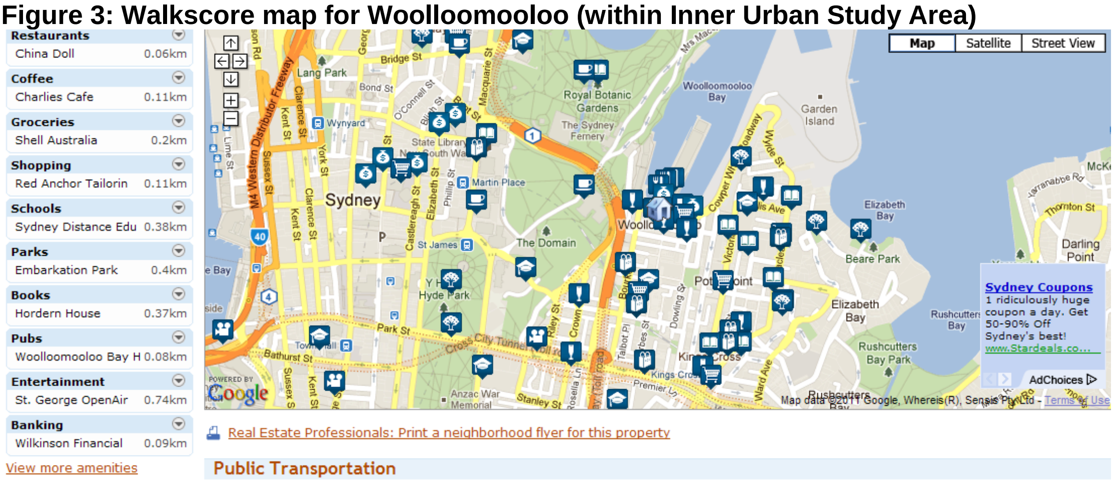


This study made use of the full complement of HTS respondents within each study area. The numbers were kept to about 100 households so that the graphic traces of trips could be clearly displayed on a map of Sydney. Too many and it would be confusing, too few and it may lack statistical significance. Within these households the population varied, with more persons living in each household in the outer areas and the least number in the centre.

Accessibility of residents to various attractors was measured using the web based "Walkscore" program. This is a measure that provides an indication of how far people have to walk to access the daily necessities of life, e.g. shops, transport nodes, sporting facilities, parks, etc. The service is accessible at http://www.walkscore.com/score/woolloomooloo-australia and provides a map of the interrogated area with the attractors shown, as per the following, for just one of the three suburbs tested within each study area (Figure 3).

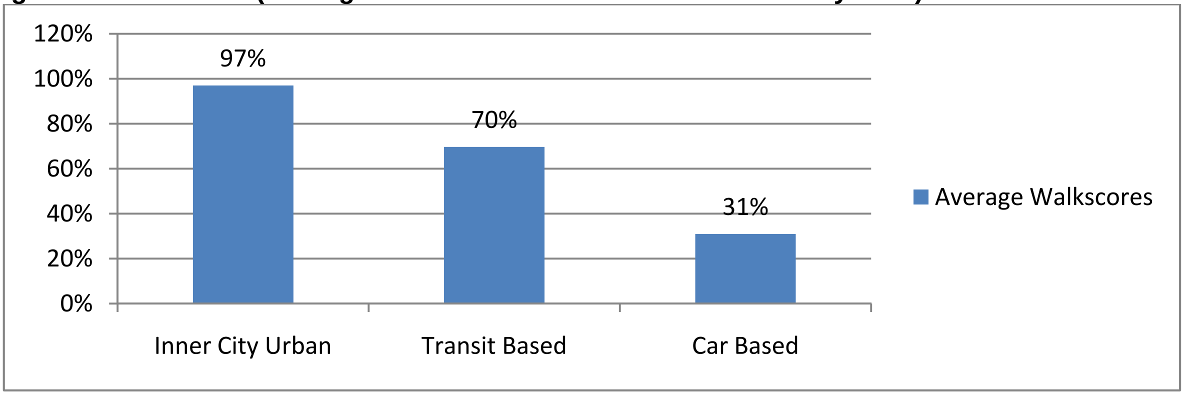
Walkscores, a web based program that measures the proximity of any location to a range of services and locations required for everyday living was used to measure accessibility. A full explanation of their rationale and methods are available at http://www.walkscore.com/.

Figure 3: Walkscore map for Woolloomooloo (within Inner Urban Study Area)



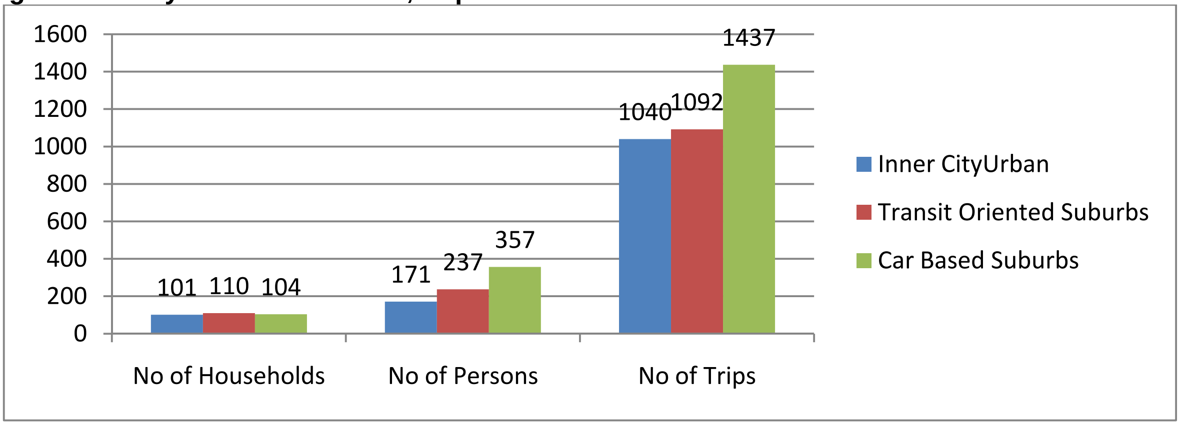
Scores were obtained for three locations within each study area, and those three scores were averaged to provide the following graph in Figure 4. The accessibility of attractors, as measured by "Walkscores", was very much correlated with density. It is also noted to be high where mixed use zoning is prevalent.

Figure 4: Walkscore (Averages of three locations within each Study Area)



The number of trips per household also increased the further out the study area was located as per Figure 5.

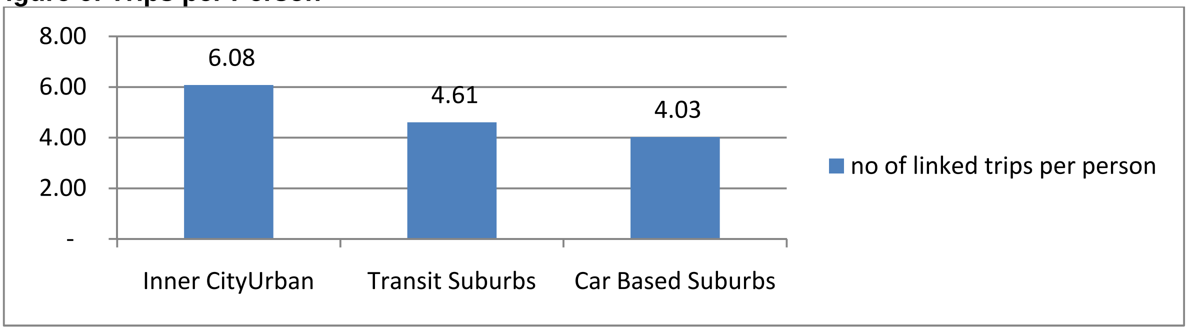
Figure 5: Study Area Households, Population and Travel



2.2 Trips and Modes

Although the number of trips increases the further out from the CBD one goes the trips per person actually dropped.

Figure 6: Trips per Person

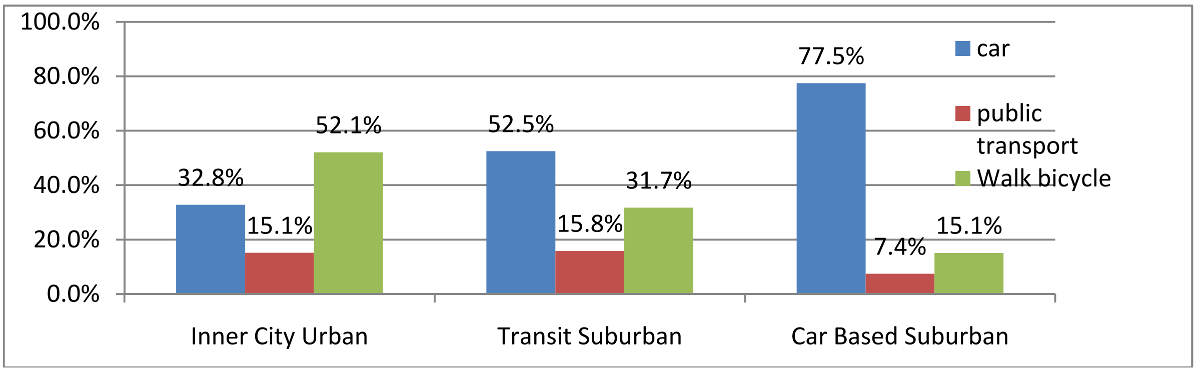


Each respondent in the inner city urban area travelled more frequently than those further out, while the outer areas had more travel in total but not as great a figure on a per capita basis. (It is noted that the respondents in the study areas made more trips than those in Sydney as a whole, which the HTS notes as being an average of 3.8 trips per person).

The modes used for this travel are shown in Figure 7 below and are consistent with the overall figures for the HTS, showing that the figures for the Inner City Urban area are not average, but those for the outer two study areas are. Public transport is not well represented in any study area. It is virtually the same in the Inner City and the Transit Study areas, despite the differences in residential density and does not provide support to the contention that public transport use increases with or because of density. The use of the car dominates

in the outer areas, but walking/cycling dominates in the Inner Urban study area, outnumbering the use of the car and public transport combined. Car use is inversely proportional to density and walking/cycling is directly proportional to density. The Transit study area has a similar profile to the Car Based Suburban study area and it is noted that the Inner City Urban study area is the only one with extensive areas of mixed use zoning.

Figure 7: Mode Choice per Study Area



2.3 Establishing Typical Trips for Measurement

2.3.1 Overall Trips

Analysis of the trip time characteristics shows that nearly two thirds of trips in all study areas were shorter than 15 minutes, and tended to be multi linked trips, as per Figures 8 and 9.

Figure 8: Trip Times

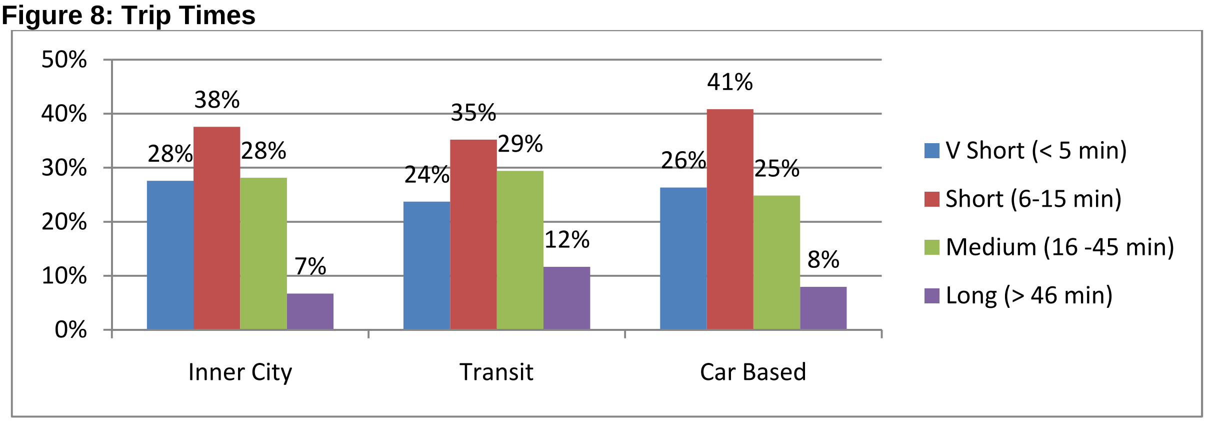
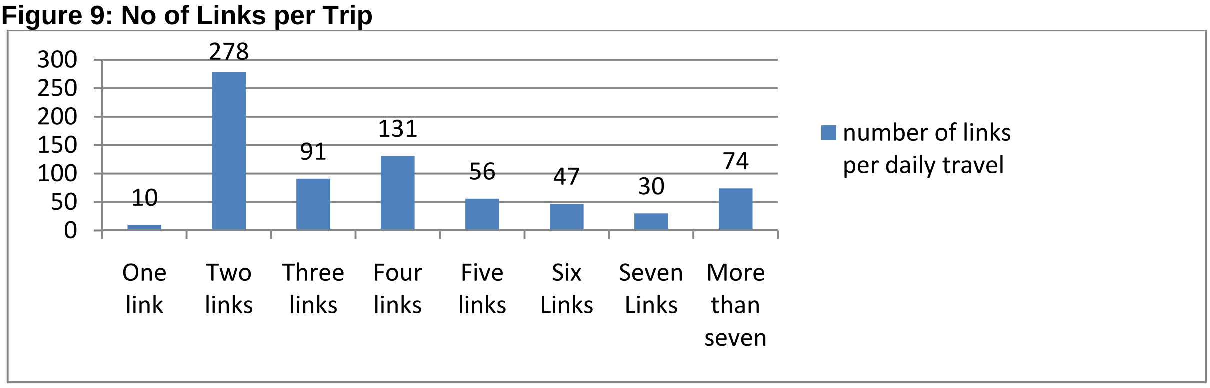


Figure 9: No of Links per Trip

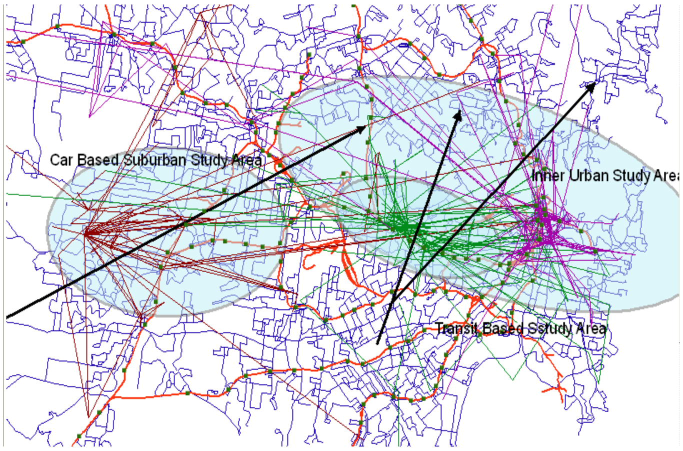


Although the two linked trip was the most numerous category when all multi linked trips are combined, 60% of trips contain more than two links, with many being quite complicated.

2.3.2 Travel Patterns

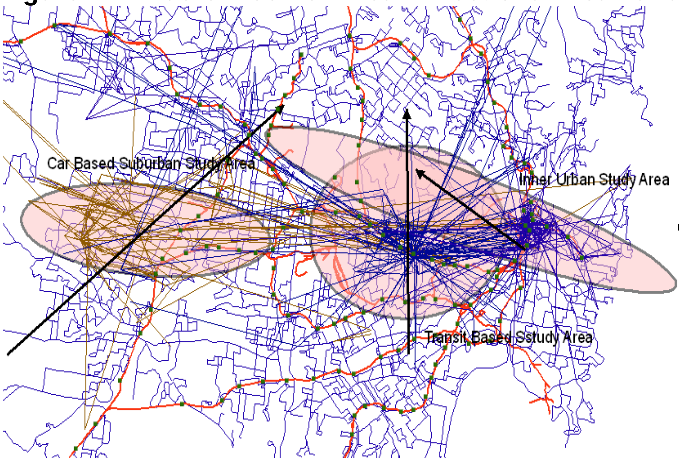
When examined in terms of income groups, there is a notable bias in the travel behaviour of the different income groups based on the standard deviational ellipse and directional means methods (Figures 10-12).

Figure 10: High Income Linear Directional Mean and Standard Deviational Ellipse



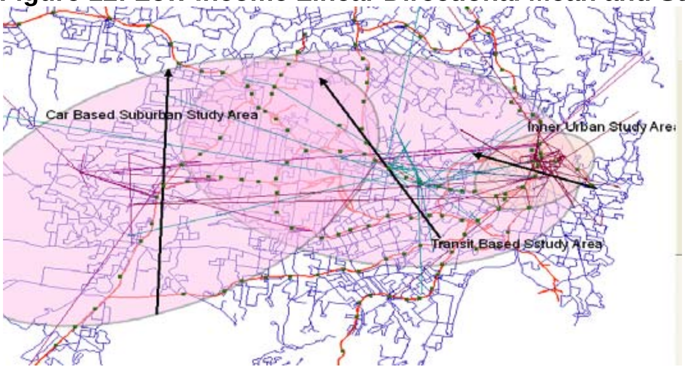
The **High Income** group travel most from the inner city, hardly at all in the middle and moderately in the outer areas. The direction of travel is distinctly to the east.

Figure 11: Middle Income Linear Directional Mean and Standard Deviational Ellipse



The **Middle Income** group do not travel as far as the high income group and their direction is more northerly.

Figure 12: Low Income Linear Directional Mean and Standard Deviational Ellipse

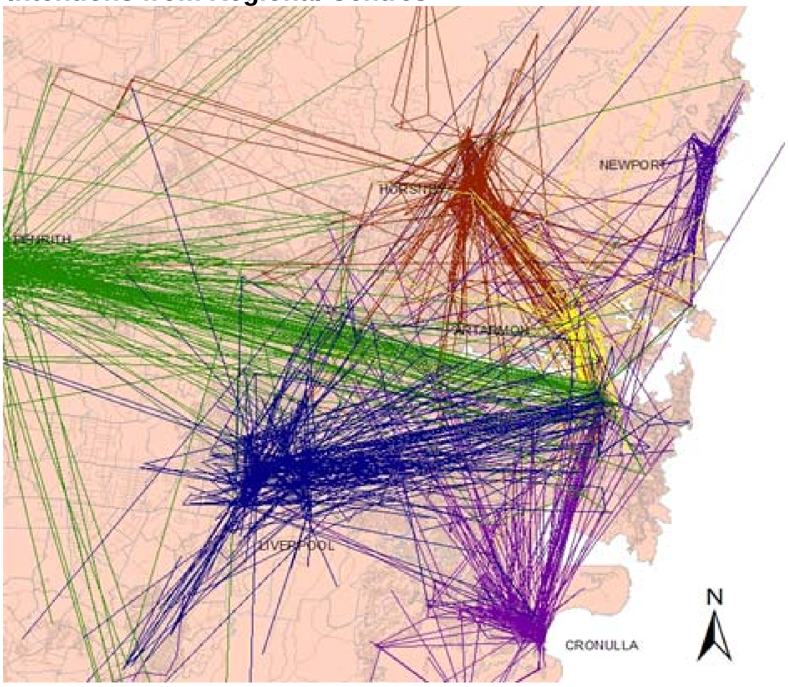


The **Lower Income** Group travel long distances in the outer areas, but only short distances in the Inner areas. Travel is in a distinctly more westerly direction.

Travel in Sydney in general appears to be similar to that from the study areas, as shown by the trips recorded from various regional centres and suburbs. This is from the same data set as was used to produce the trips from the three study areas above. These trips are shown in Figure 13 and exhibit a similar disbursed pattern, with outlying areas having a distinct bias towards the CBD. Some suburbs such as Hornsby, Cronulla and Artarmon also have very disbursed patterns of destinations, with a barely discernable bias towards the CBD--

consistent with the overall statistics provided by the HTS. This shows travel to the CBD being only a relatively small fraction of the overall journey to work trips (Xu and Milthorpe, 2010), which are only a relatively small fraction of the overall trips (BTS, 2010).

Figure 13: Travel Intentions from Regional Centres



From the evidence of the tabular and graphic data, it is concluded that trip patterns can be characterised as being of short distance, linked and very dispersed in their destinations. The trip patterns do not suggest high levels of self-containment, with a large number of trips moving outside the origin local government area (LGA). This supports earlier studies showing the diversity of trips and the lack of "co-location" associated with travel to work (Parolin, 2005).

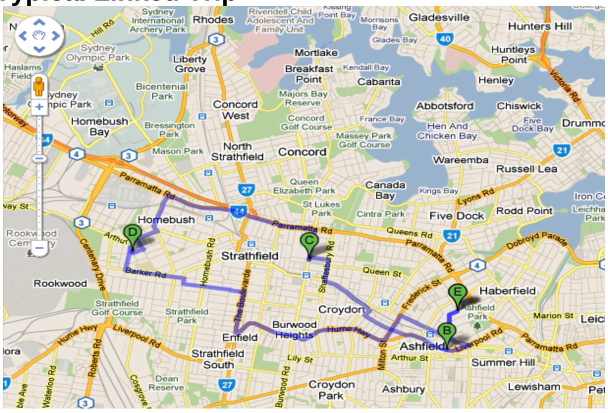
2.4 Measurement of Typical Trips

The study then assembled some typical trips that were representative of the types of trips established by examination of the HTS data. Two types of trips were studied in detail; (i) from each of the study areas to a remote location (in this case Castle Hill) and, (ii), linked trips from a household location within each study area to a series of locations comprising:

a) from a home
b) to a local school
c) to a significant local shopping area
d) to a more remote area of business
e) back to the home.

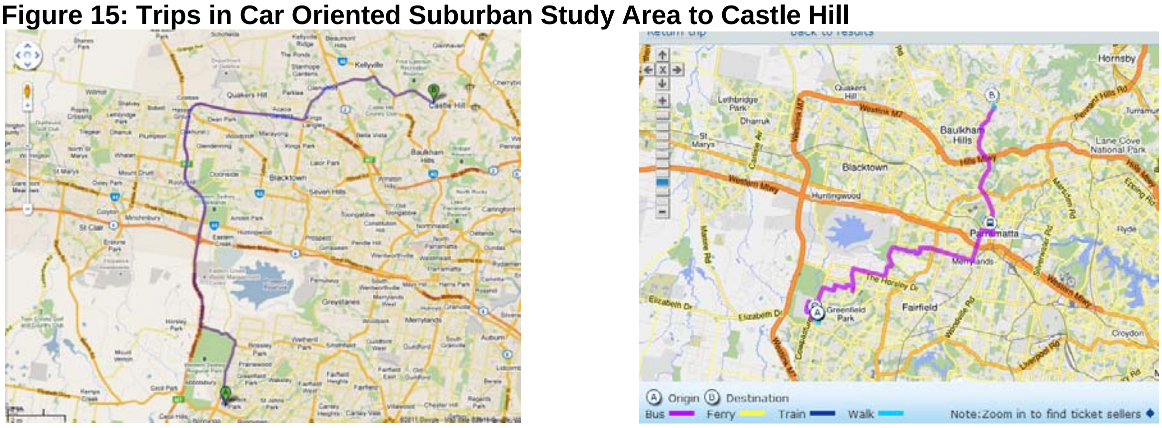
The trip examined in the study from the Transit Suburban study area, in this case by car, is as shown on Figure 14:

Figure 14: Transit Area Typical Linked Trip



The routes for the trips to Castle Hill from the Car Based study area are shown on Figure 15:

Figure 15: Trips in Car Oriented Suburban Study Area to Castle Hill



Car | Public Transport

(Note that the car takes the expressway (M7) and the bus takes a circuitous route comprising two separate buses. This feature contributes to the time taken for travel by public transport).

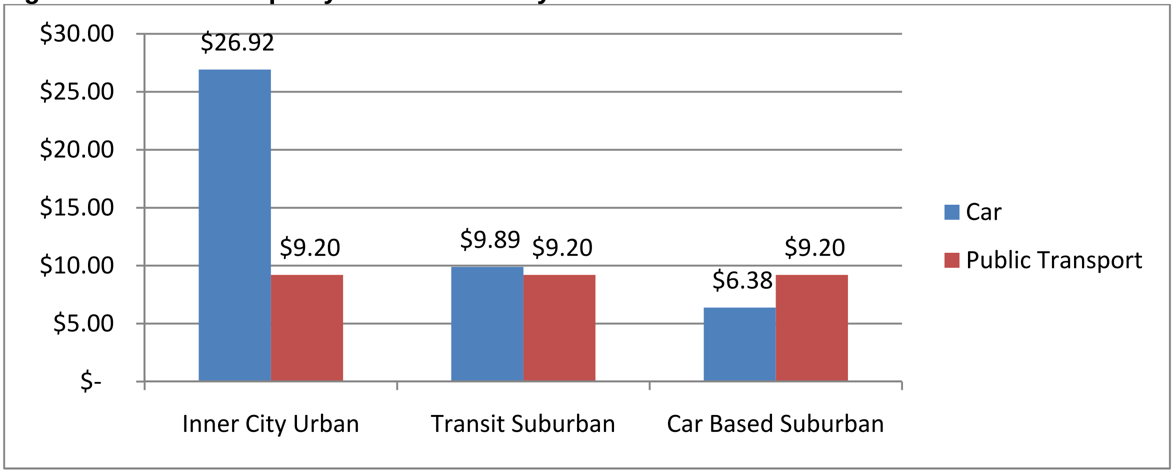
The routes and times for car use were established using Google Maps linked trip planning facility, and for public transport by the Department of Transport web pages for its trip planning web site (http://www.131500.com.au/plan-your-trip/trip-planner). This provided the means of establishing the appropriate public transport modes, routes and times taken to undertake these journeys.

Travel costs in the study were established using out of pocket expenses only. For the car, the costs consisted of those ‘felt’ costs of petrol, parking and tolls, and for public transport the fares were for a single person only. The use of total costs for the car, as provided by the NRMA, was extensively considered in the study. However, this approach was ultimately rejected, as it was noted that most households have cars that are generally available, people having them for all sorts of reasons, and that once owned it is the ‘felt’ incremental costs, not the total costs, (which are committed in any case) and which determine if an individual journey will be taken by car or by public transport, or taken at all (de Donnea, 1972, Hanson and Giuliano, 2004).

2.5 Time and Cost of the Typical Trips

The results of the measurement of these trips for time and cost are on Figure 16 as follows:

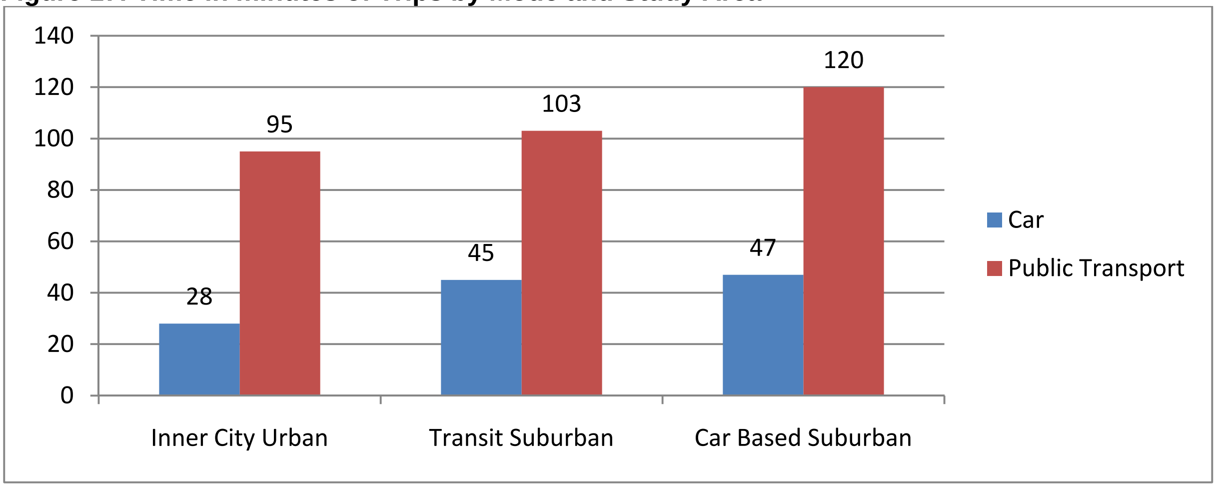
Figure 16: Cost of Trips by Mode and Study Area



The trip examined in the Inner City Urban study area took in a business address in the CBD, which necessitated a costly ($20/hr) parking station. Cost was therefore punitive in the Inner City, but largely because of this parking fee. If this particular (possibly avoidable) influence is discounted, then the cost does not become such a distinguishing feature between modes. However, it is noted that it is a factor that would encourage car use in the Car Based Suburban study area as the costs of trips by car in that study area were actually cheaper, in out of pocket expenses, than for public transport. So, it is noted that if a household already owns a car, then it is unlikely that someone in that household would use public transport unless by necessity. This would be especially so (something applying to all areas) if more than one person is travelling, as more passengers multiplies the actual cost of public transport but does not materially affect the felt cost of using the car.

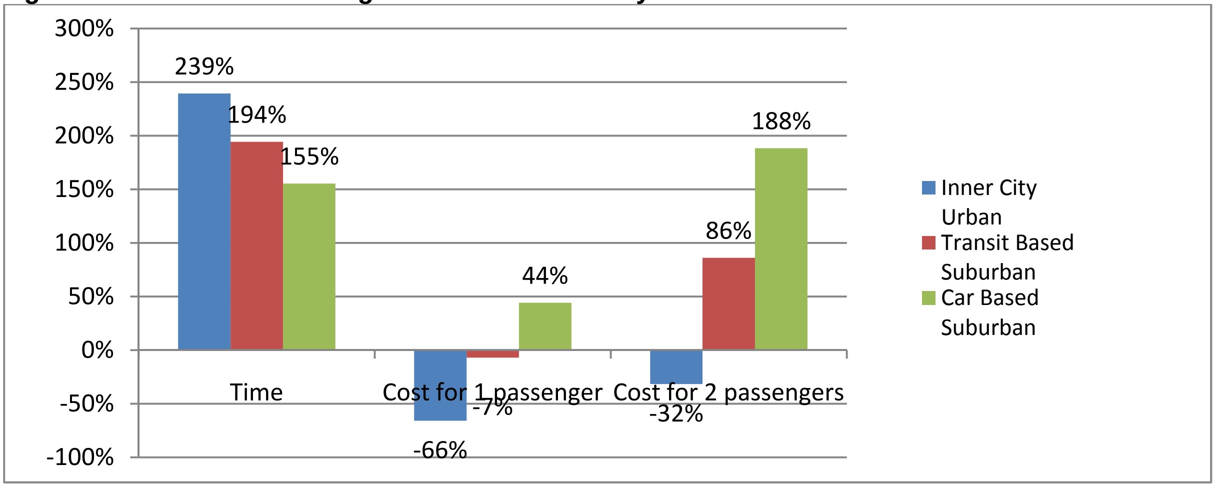
The time taken though is different by very large margins as recorded in Figure 17. The car is just so much more efficient in travelling to a series of locations. Public transport takes from two to three times as long in nearly all the circumstances examined in the study

Figure 17: Time in minutes of Trips by Mode and Study Area



The combined effect of time and cost is shown below in a graphic where the 0% line shows no advantage to either the car or to public transport, but figures above this line show an advantage to the Car. It is evident that the car is superior to public transport in the time taken and if two persons are required to travel, then the cheaper cost would not discourage car use. The cost of public transport also increases with the number of modes used as separate ticketing is generally required for each change of mode. These figures include multi modes, so that a single mode would be correspondingly more economical. This relative performance recorded in the study of the car compared to public transport is graphed in Figure 18.

Figure 18: Relative Advantage of Time and Cost by Mode



This contrast in part to the findings on time and cost with the findings of the summary report for 2008/9 of the Bureau of Transport Statistics, (BTS, 2010) which shows that:

- The most prevalent reasons for use of the car for the journey to work includes preference for convenience/independence of car, Public Transport services are indirect, slow and do not go where required.
- The most prevalent reason for using public transport for the journey to work is that it avoids parking problems, is cheaper, faster and that a car is not owned.

Reasons for these differences are suggested by the fact that commuting, work related business and education trips only account for a third of all trips. The study being described uses all journeys, not just journeys to work, The BTS (2010) show that discretionary activities are the largest group of trips by purpose, and within that group social/recreational being largest, then shopping. These trips do not necessarily have a CBD or regional centre focus

2.6 Analysis of Time and Cost

2.6.1 Comparison of Operational Times

It is known that cars are generally present in most households (BTS, 2010), and are available 24 hours a day and 7 days a week, i.e. 100% availability and no waiting time.

Public transport, as measured on the routes in this study, is available only 74% of the day and at only a frequency of one service every:

- 13 minutes in peak hour
- 18 minutes generally, and
- 22 minutes in the evening

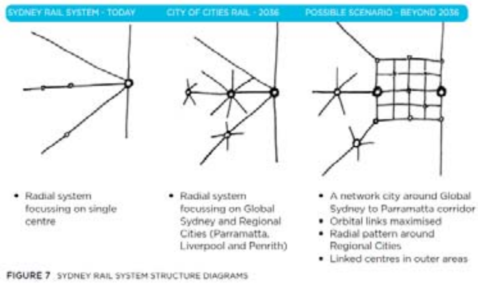
This represents a sizable reduction in frequency over the car and not close to a 10minute service considered by some (Newman and Kenworthy, 2006) to be the minimum acceptable. These are averages as well, and buses do not have the same extended times of service as trains. As trains cannot provide a Sydney wide service on their own, it follows that the public transport service is limited by the operating times of the buses for most areas of Sydney.

2.6.2 Analysis of Coverage of Public Transport Services

Having looked at availability and frequency of operation, there is another significant characteristic that affects travel time, and that is coverage. Does the nature of the route layouts have the potential to affect greatly the time advantage of car travel? The routes used

by public transport are shown on Figures 19 and 20, including each mode diagram and that from the Metropolitan Plan which seems to be representing their conceptual thinking.

Figure 19: Conceptual Public Transport Diagram and Ferry Diagram



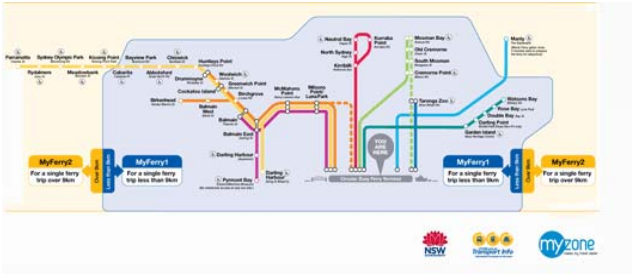


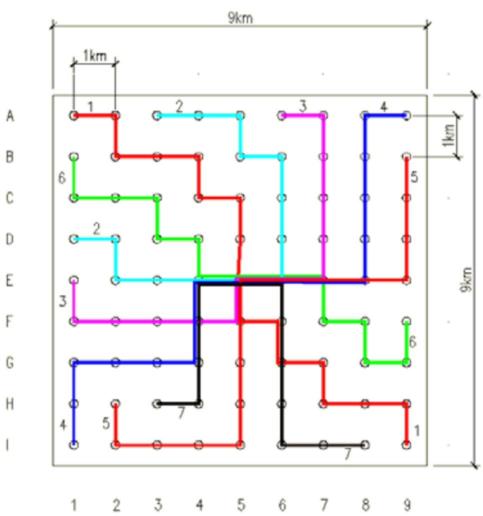
Figure 20: Bus and Rail Diagrams

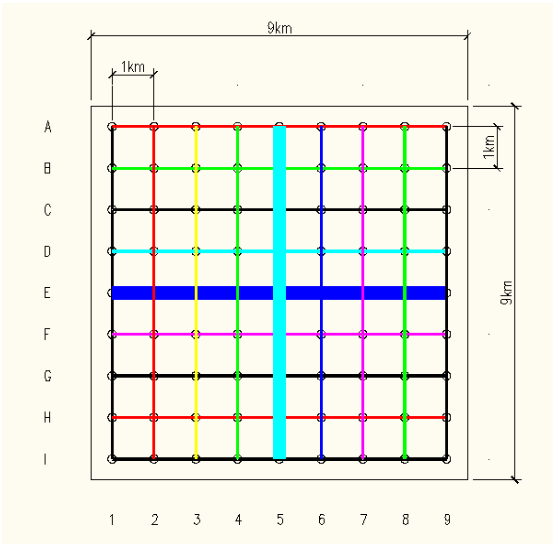
For the purposes of the study, Sydney was seen to have routing of public transport that was termed a Branching Tree because of its focus on the CBD and the regional centres.

It is difficult to find much research work that examines the routing of public transport and, accordingly, the following work was adapted from a consideration of the simple model of a city called “Squaresville”. The use to which the author’s put this model is somewhat different from others (Nielsen and Lange, 2008, Mees, 2000), but it has proved useful, as other authors have found, in establishing some principles of operation.

Squareville is a grid of nodes on a square layout to represent potential transport nodes of a city. The manner in which these nodes are connected is a way of representing the transport routes of a city. Figure 21 is a representation of a Branching Tree structure (typical of general public transport layout in Sydney) and a Grid or Mesh structure, a concept common in overseas cities. Both structures have a CBD at the centre.

Figure 21: Branching Tree and Mesh Routing

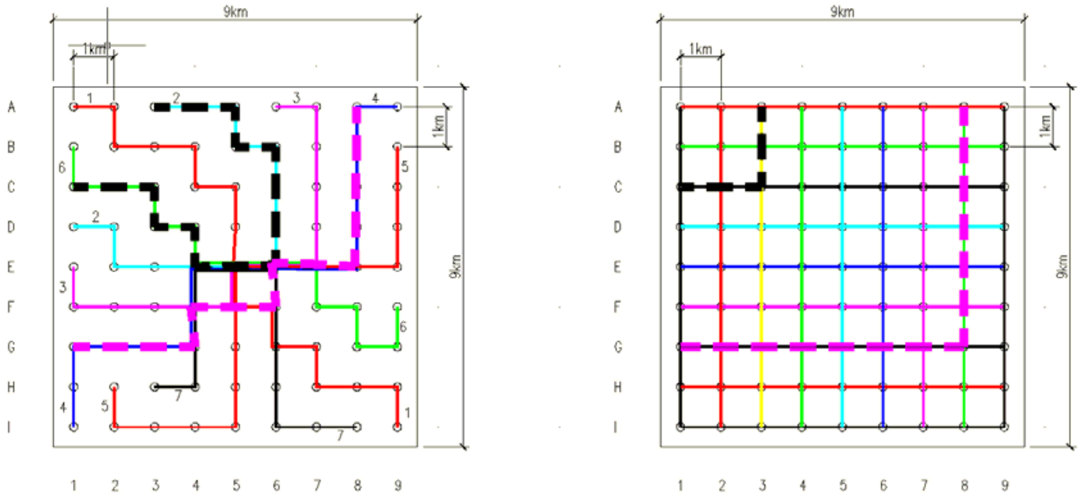




In the Branching Tree structure all routes pass through the CBD, while in the Mesh system there occurs an increase in the capacity of those routes that pass through that CBD node.

The distance between nodes by either of these systems can be measured. For instance, to go from C1 to A3 and say G1 to A8, would look as in Figure 22.

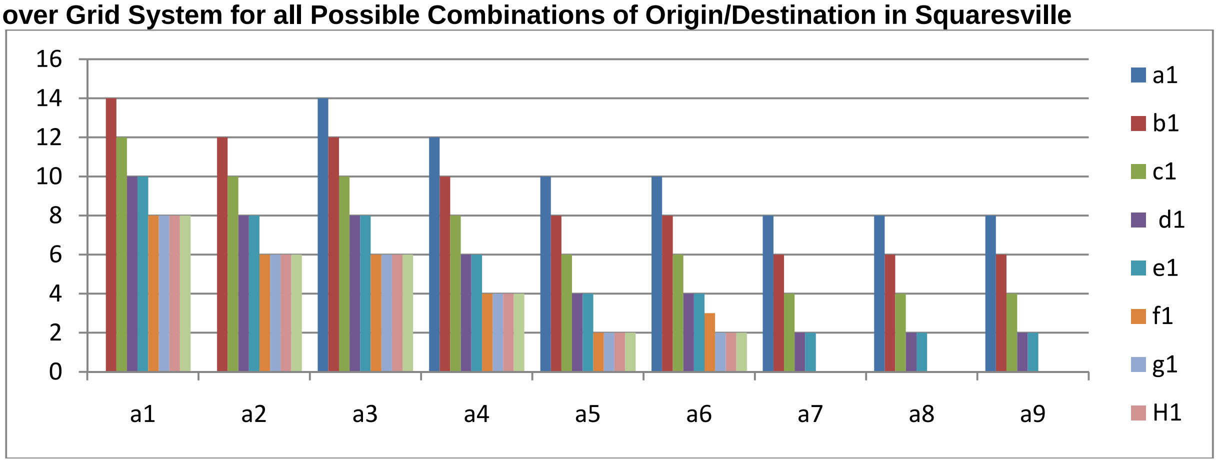
Figure 22: Access to a single remote point in Squaresville



The differences in distance of each system between all possible combinations of origins on the x axis to destinations on the y axis were measured and recorded for each trip for both the Branching Tree and the Mesh system. This reveals that the Mesh is never longer than the Branching Tree and that as the straight line distances between origin and destination increase, the differences on both systems diminish. This shows theoretically what seems to be an inherent characteristic of the Branching Tree that it is less efficient for short trips as compared to the Mesh system. It is noted that the short trips are the ones that dominate in Sydney.

A graph of these differences from each node to another is shown in Figure 23.

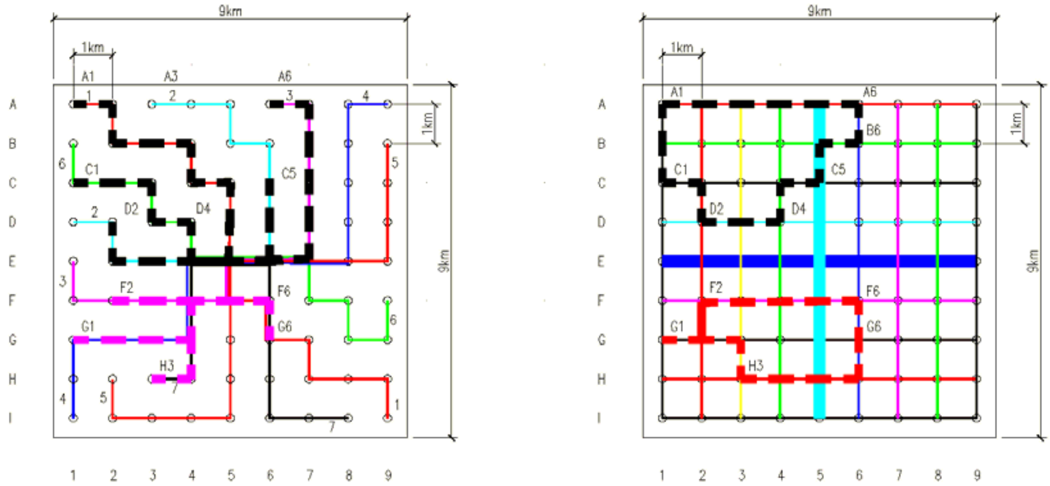
Figure 23: Additional Distance in Kilometres by Public Transport of Branching Tree System over Grid System for all Possible Combinations of Origin/Destination in Squaresville



The closer the origin and destination points, the larger the difference in distance travelled on the two systems are. This is shown by the greater number of larger graph elements to the left of the graph. The Mesh system is just more efficient for trips that are close, but that occur on other branches of a Branching Tree network. Destinations can be as close ‘as the crow flies’ but a long way by the available public transport routes of a Branching Tree. This is consistent with the longer trips (over 30 kms) being the only category of travel recorded in the HTC data provided, where public transport was more frequently used than the car for the journey to work. It is noted that this length of trip was not frequent and did not constitute more than 2%

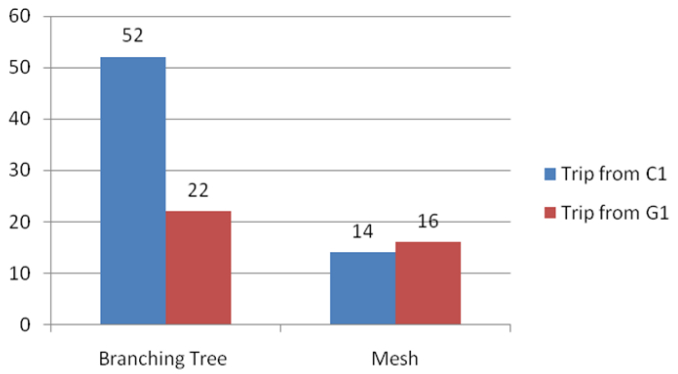
of trips in the Inner City Urban study area, or 7% in the Car Based Suburban study area. Linked trips that go to several destinations and then return home are no more efficient on the Branching Tree system as shown on Figure 24. In the study these recorded the traces that resulted from two separate trips but with five destinations as linked trips for each system: This was the theoretical equivalent of the multi linked chains of travel investigated for time and cost performance of typical trips in Sydney reported in the previous section.

Figure 24 Linked Trips to Multiple Destinations on Branching Tree and Mesh Systems



When the length of these trips were recorded, the results were no better for the Branching Tree system than the previous investigation into single destination trips from any location. The length of trips was recorded and graphed as shown in Figure 25.

Figure 25: Comparison of Length of Trips



Although Sydney's system is not a pure Branching Tree, it is fundamentally different from a number of transport systems in other cities of the world. Several of these are considered next.

2.7 Examples of Mesh Routing from other cities

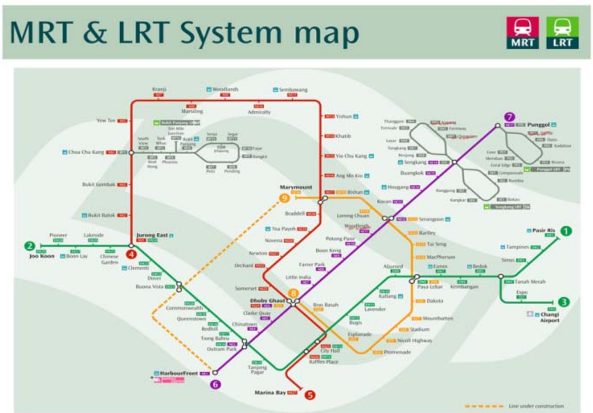
Figure 26: Paris Metro

Paris has one of the original urban rail systems and it is a Mesh. Its use can get someone from virtually anywhere in the original city to anywhere else in the original city with a single change of trains. Of course, Paris did not have a CBD to start with and did not have the need for a CBD bias like naturally developed in Sydney. The result is that travel across the city is relatively easy and time efficient.

Figure 27: Moscow Underground

Moscow is a system planned by a central government. It too is a mesh system with tails that extend to the perimeter of the built up city. Again, there is no bias towards a specific point in the centre, only the capacity to move randomly around the city by changing trains when necessary.

Figure 28: Singapore Metro



Singapore is a direct competitor of Sydney for South East Asian city investment. Its new subway system is different from that in Sydney in that it is a mesh system without a CBD bias, (but with a very large CBD). The system extends over a large part of the city and requires the passenger to make appropriate changes of lines to get to a particular destination. It runs frequently and has a very high capacity.

These systems are notable for the uncomplicated “there and back” simplicity of each route; (there is no branching of individual lines to serve other areas, the passengers make the transition to lines going to other areas by walking from one line to the other), as well as the coverage of the whole system. This is generally within a comprehensive integrated ticketing regime so that changes from one mode or route to another do not involve additional expense. This provides a system that is inherently more efficient, safer and effective.

2.8 The Metropolitan Plan

The intention outlined in the Metropolitan Plan appears to be to expand the current rail system and to substantially augment the number of buses. However, if the routes those buses take do not provide a service that enables greater availability, coverage and frequency, then the ability to service the non CBD market will be limited. Using the bus to feed the rail service from all areas would provide a more mesh like operation. This has the possibility to work much more effectively, although it is noted, that without integrated ticketing across modes and links of the same mode; there is a substantial impediment to general use of public transport. The existence of the Senior's ticket, with its distance independence, modal transferability and daily validity, is in stark contrast to the prevailing ticketing regime in Sydney with separate ticketing for different modes and distance dependence. The only generally available ticket to match the Pensioners $2.50 fare is the MyMulti which at over $47 for much the same service is a more expensive option.

The diagram of note that summarizes the intent and vision of the Plan is shown in Figure 29.

Figure 29: Evolving Structure of Sydney Rail System as in the Metropolitan Plan

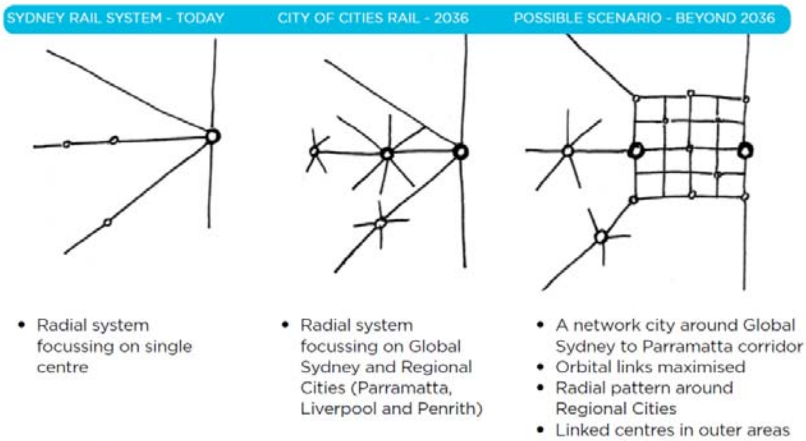


FIGURE 7 SYDNEY RAIL SYSTEM STRUCTURE DIAGRAMS

The next twenty years of development effort would seem to be directed towards reinforcing the existing Branching Tree network, and only in the very long term does the possibility of a Mesh type system provide any hope of an 'anywhere to anywhere' system of public transport, and then only in the centre. (This belies the fact that tracks once laid tend to be there for multiple decades, if not centuries).

3 Conclusions and recommendations

3.1 The Urban Travel Market

The largest 'market' for urban travel is for smaller, often linked trips to diverse destinations. Although there is no doubt that the public transport system is serving a real need in catering to the CBD commuter, it is just as evident that many other trip types and a greater proportion of trip numbers are not addressed.

3.2 Route Structure of Public Transport and the Car

By concentrating on the CBD commuter, public transport has developed a route structure that is basically a Branching Tree with all the inherent disadvantages and inefficiencies of that structure compared to a Mesh network. The road system on the other hand presents to the user as a perfect mesh system with almost complete flexibility of use. The Metropolitan Plan could bring forward its plans for mesh routing for the public transport system.

3.3 Competing Modes in Sydney

Not only does Sydney have a relatively inefficient Branching Tree network for its public transport, it tends to have several competing ones with only minimal modal integration. Separate ticketing adds to this effect and provides a disincentive to use public transport. The network as a whole is poorer for not being able to utilise these competing public transport systems as a single network. Greater attention could be given to fostering modal integration.

3.4 Influence of Separate Ticketing

Each system seems to have developed the need to provide its patrons with its own version of getting to the CBD and the regional centres. For example, the MetroBus appears to compete with the trains to get people from one regional centre to another, and has developed a network of regional centre routes that are already served by train. The bus competes with the train on the Bondi Junction to CBD run and the Bondi to Chatswood run. The ferry system offers services in direct competition with the trains (Parramatta) and the bus (Manly). The Metropolitan Plan could bring forward plans for integrated ticketing to integrate the modes.

3.5 Density/Quality Debate

This study has provided strong support for the quality side of the debate and only limited support for the role of density, given that the use of public transport was virtually the same in the Transit Suburban and the Inner City study area which has much higher density than the Transit study area. However, the use of the car correlated strongly with lower densities, but it was walking/cycling that seemed a closer fit to an increase in density than public transport. The role of mixed use planning (and the quality of the public transport service) is suggested as possible best explanations for these phenomena. The Metropolitan Plan could foster the more extensive use of mixed use zones to allow a closer arrangement of residents and attractors in any area, with a potential reduction in car dependence.

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