ANALYSIS OF ACCESSIBILITY TO JOBS BY CAR IN THE CITY OF SYDNEY, AUSTRALIA

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Abstract : Low density urban sprawl generates a greater need to travel than more compact structures of mixed land uses in which the physical separation of activities is small. One way to reduce travel needs would be to bring homes, jobs, and service together in a relatively compact urban centre to achieve a high level of accessibility with little need for movement. Recently, research has focused on the debate of the urban form contribution to reduce urban travel and car dependence and to achieve a more sustainable city. One variable to define urban form is accessibility to jobs. Accessibility concept can be used to analyze relative job-housing location. Using journey-to-work (JTW) Census data over a 35-year period from 1961 to 1996 in Sydney, this paper analyze accessibility to jobs in Sydney, Australia by applying several methods such as dispersal index, Z-score, lorenz curve and Hansen Index.
The results indicated that both housing and employment have moved away from the CBD towards the outer areas. Decentralization of both residential workers and employment was followed by an increasing use of car. Because the employment location in the outer ring is much easier to reach by car, this leads to an increasing car dependence by residents. If the decentralization trend continues into the future without a change to the public transportation service, it is expected that the proportion using car will increase by about 12.7 percent of the 1981 share. The mean trip length by car is predicted to increase by about 20.5 percent from its 1981 value. This finding indicates that the change in the relative jobs-housing location was followed by a change in travel patterns.

Keywords: accessibility, jobs, private car.

ANALISIS AKSESIBILITAS KE LOKASI TEMPAT KERJA DENGAN KENDARAAN PRIBADI DI KOTA SYDNEY, AUSTRALIA

Abstrak : Pertumbuhan kota yang menyebar dengan kepadatan rendah menyebabkan kebutuhan perjalanan yang lebih tinggi daripada kota dengan struktur kompak, tata guna lahan campuran, dimana pemisahan antar aktivitas relatif kecil. Salah satu cara untuk mengurangi kebutuhan perjalanan adalah dengan menempatkan permukiman, pekerjaan dan jasa pelayanan dalam suatu pusat kota yang kompak untuk memperoleh aksesibilitas yang tinggi dengan kebutuhan perjalanan yang rendah. Fokus dari riset-riset saat ini adalah pada perdebatan tentang kontribusi struktur kota untuk mengurangi perjalanan dan ketergantungan pada kendaraan pribadi serta mencapai kota yang lebih ramah lingkungan. Salah satu variabel dari struktur kota adalah aksesibilitas ke lokasi tempat kerja. Konsep aksesibilitas dapat dipergunakan untuk menganalisa lokasi relatif antara permukiman dan tempat bekerja. Dengan menggunakan data perjalanan kerja untuk periode 35 tahun dari 1961 sampai 1996 di Kota Sydney, paper ini bertujuan untuk menganalisa aksesibilitas ke lokasi tempat kerja di Kota Sydney, Australia, dengan mengaplikasikan beberapa metode diantaranya: dispersal index, Z-score, lorens curve, dan Hansen index.
Hasil studi memperlihatkan bahwa terjadi pergeseran lokasi permukiman dan pekerjaan dari pusat kota ke arah luar kota. Desentralisasi dari lokasi permukiman dan pekerjaan diikuti oleh peningkatan penggunaan kendaraan pribadi. Karena lokasi pekerjaan di daerah luar kota jauh lebih mudah dicapai dengan kendaraan pribadi, hal

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ini meningkatkan ketergantungan pamakaiannya. Jika kecenderungan desentralisasi tersebut terus berlanjut dimasa mendatang tanpa adanya perbaikan sistem angkutan umum, diperkirakan penggunaan kendaraan pribadi meningkat sekitar 12,7 prosen dari kondisi pada tahun 1981. Rata-rata panjang perjalanan dengan kendaraan pribadi diperkirakan meningkat sekitar 20,5 prosen. Hal ini menunjukkan bahwa perubahan lokasi relatif antara permukiman dan pekerjaan diikuti oleh perubahan pola pergerakan.

Kata kunci: aksesibilitas, pekerjaan, kendaraan pribadi.

INTRODUCTION

Transport is important for development and it conveys many benefits. It allows personal mobility for both work and leisure activities. It supports social and economic development. Despite the unquestionable socio-economic benefits of transport, it also creates substantial and steadily adverse effect on environment. Much of the environmental debate has focused on the notion of 'sustainable development' which is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 8).

Newman and Kenworthy (1999) stated that land-use patterns and built form affect intrinsic energy needs as well as the efficiency with which energy needs can be met. Low density urban sprawl, for example, generates a greater need to travel than more compact structures of mixed land uses in which the physical separation of activities is small, and the technical and economic viability of certain energy technologies and transport systems are affected by factors such as urban density and the location and mixing of different land-use. Interaction between urban structure and energy systems takes place at all scales from that of the individual building to the region. Therefore, energy-conscious land-use planning at any one level alone is unlikely to make a major contribution to sustainability.

One way to reduce travel needs would be to bring homes, jobs, and service together in a relatively compact urban centre to achieve a high level of accessibility with little need for movement. Many studies suggested that concentration of development is an energy efficient form (Edwards, 1977; Rickaby, 1987). The European Commision's Green Paper on the Urban Environment concluded that the existing high-density compact city should be the focus of future development. However, there are some possible contradictions of this policy to the energy efficiency, quality of life, green city and renewable energy sources (Breheny, 1995). Some studies proposed 'decentralized concentration' as an efficient alternative in terms of travel and energy requirements (OECD, 1996).

The postwar period has been one in which trends in both land-use and travel patterns have reinforced each other to produce an increasingly mobile society. Higher levels of mobility have benefits for the individual and for the economy, but also impose costs, many of which are externalized. Rapid growth in car ownership has permitted more dispersed patterns of urban development; these land-use patterns in turn require longer journeys for most daily activities and have become increasingly difficult to serve by energy efficient modes of transport.

The energy and environmental implications of these trends are alarming because predicted traffic growth is likely to outstrip measures to improve the energy efficiency and environmental performance of vehicles unless other policy measures are introduced (Newman and Kenworthy, 1999). Policies for sustainable urban development should therefore include measures to reduce the need for move-

ment and to provide favourable conditions for energy-efficient and environmentally friendly forms of transport. According to Black and Suthanaya (2002), land-use planning has a key role to play in the attainment of these objectives.

Recently, research has focused on the debate of the urban form contribution to reduce urban travel and car dependence and to achieve a more sustainable city. Changing urban design and form through the relative location of homes and other land use activities has some potential as a longer term option for reducing travel demand and ultimately energy consumption and CO_2 emissions from road transport. The shape and configuration of urban settlement and the location of activities can affect energy requirements considerably. There seems to be evidence that the prevailing urban form in Australia's cities is a significant factor in its considerable car dependence.

One variable to define urban form is accessibility to jobs. Accessibility concept can be used to analyze relative job-housing location. Job accessibility is described by the availability of jobs and the effort to reach them in terms of travel distance, travel time, costs (or a combination of any or all of these). A zone is said to have good job accessibility if jobs are located nearby. Conversely, a zone is said to have poor accessibility if jobs are located a long way away. Job accessibility is often used as a tool for examining the equity aspects of development (Black and Conroy, 1977). Hansen (1959) asserted that land-use development is related to accessibility, which he described as a measurement of the spatial distribution of activities about a point, adjusted for the ability and desire of people or firms to overcome spatial separation.

Using journey-to-work (JTW) Census data over a 35-year period from 1961 to 1996 in Sydney, this paper analyze accessibility to jobs in Sydney, Australia by applying several methods such as dispersal index, Z-score, lorenz curve and Hansen Index.

LITERATURE REVIEW

Dispersal Index

The relative dispersion of job location to housing location is calculated using dispersal index (DI). Dispersal index is the ratio of the average job distance from the CBD to the average housing distance from the CBD. Brotchie (*et al*., 1996) introduced the use of dispersal index as follows:

$$DI = x/y \quad (1)$$

Where:

DI = dispersal index
x = average job distance from the CBD
y = average housing distance from the CBD

The value of 1 indicates that on the average, jobs and housing are located at the same distance from the CBD. A ratio higher than 1 also indicates a more balance distribution of housing and jobs. The higher the ratio than 1 indicates that the housing location is more centralized than the job location. On the other hand, a ratio lower than 1 indicates that the opposite applies and that the job location is more centralized than the location of housing.

Z-Score

There is an infinitely large number of normal curve – one for each pair of values for μ and σ. It is neither possible nor necessary to have different tables for every possible normal curve. The standard normal distribution is a transformation of the normal distribution. In the standard normal curve, $\mu = 0$ and $\sigma = 1$. This standard normal curve can be displayed in terms of Z-scores as indicated in Figure 1. The standard normal curve helps to simplify the calculation of probabilities for normally distributed populations. Because not all normally distributed

random variables have $\mu = 0$ and $\sigma = 1$, it is needed to transform the variable so that $\mu = 0$ and $\sigma = 1$. It can be done by using the Z-score, which is calculated as follows (Lee, 1993, p.257):

$$Z = \frac{X - \mu}{\sigma} \qquad (2)$$

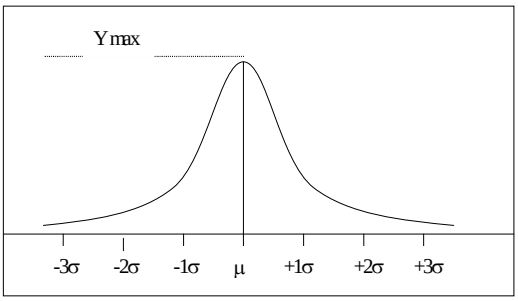

Figure 1. Normal Probability Distribution with $\mu = 0$ and $\sigma = 0$.

Lorenz Curves

Lorenz Curves have been used in a number of geographical applications, as well as by researchers in other disciplines in respect of non-spatial data (Walford, 1995). Figure 2 illustrates the Lorenz curve for employment data and the deviation away from the diagonal suggests that there has been a reduction or shift in the number in employment for 1996.

When the Lorenz curve does not follow the diagonal, there has been a change in the spatial distribution of the variable, or the phenomena show some evidence of spatial separation. The point at which the perpendicular distance of the curve from the diagonal is greatest indicates the areas which are most dissimilar. This distance provides the index of dissimilarity, Ds, which may be obtained in three ways (Walford, 1995, p.371)

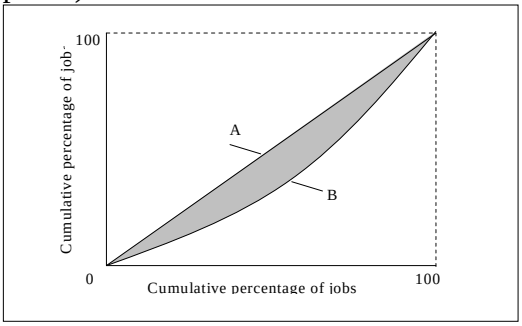

Figure 2. Lorenz Curve

Calculation of dissimilarity index (Ds) based on Walford (1995):

$$Ds = \sum | Xi - Yi| / 2 \qquad (3)$$

Where:

Xi = the unaccumulated percentages for variable X

Yi = the unaccumulated percentages for variable Y

The dissimilarity index can be used for a series of matched variables in order to compare different area patterns. The technique requires that the data are held in the form of frequency counts for the two variables and therefore do not include any negative values.

Job Accessibility

The common criteria in quantifying job accessibility have been to use travel time and/or distance as a measure of frictional factor. The measure of job accessibility itself can be quantified in numerous ways, for example, by measuring the total number of jobs located within a specified distance from a residential zone or by using a job accessibility index based on Hansen's formula (Hansen, 1959).

Job accessibility as measured by a total number of jobs located within a specified distance of a zone, is a relatively simple measure of physical accessibility that does not allow for any spatial discounting of jobs (Black and Conroy, 1977). It is a summation of jobs located within a nominated distance in all direction from a zone.

An accessibility index based on Hansen's definition discounts the jobs contribution to the accessibility values by the jobs' respective distance from the zone. The Hansen-based job accessibility index is used in this study and expressed as follows:

$$A_i = \sum_{j=1}^{n} Ej / d_{ij}^{\alpha} \qquad (4)$$

where:

Ai = accessibility index of zone i;
Ej = number of jobs in zone j;
D_{ij} = distance between zone i and j; and
α = the calibration parameter.

The above equation shows that job accessibility increases with an increased number of jobs but decreases when the distance to get to those jobs increases. The further away the jobs are from the zone, the less they contribute to the zone's accessibility value because of "spatial discounting".

METHODOLOGY

Sydney is a good, general, study case because of its physical characteristics and historical development which are not dissimilar to many other Australian and North American cities. Sydney Statistical Division defined by the Australian Bureau of Census, comprising 44 local government areas (LGA) (see Figure 3). The 44 LGAs were grouped into three regional rings: inner, middle and outer ring. Data used in this study is journey-to-work census data.

The journey-to-work census data, which forms the basis for this study was provided by the New South Wales Department of Transport, Transport Data Center (TDC). Microsoft Access was used to compile relevant cross-tabulations and summaries. Tabulations were then converted to Microsoft Excel spreadsheets to allow presentation and modification of format. Data sources are the 1961, 1966, 1971, 1976, 1981, 1991, and 1996 Journey-to-Work data for Sydney Metropolitan Area. The Australian Bureau of Statistics (ABS) conducts the Census and the data are aggregated from census tracts for the Statistical Local Area (SLA) levels and cover 44 Local Government Areas.

To evaluate the relative dispersion of jobs to housing, a dispersal index (DI) is calculated. Lorenz curve is used to test the hypothesis that the variables are similarly distributed over time. From the Lorenz curve, the similarity of the variable distribution over time can be visually inspected.

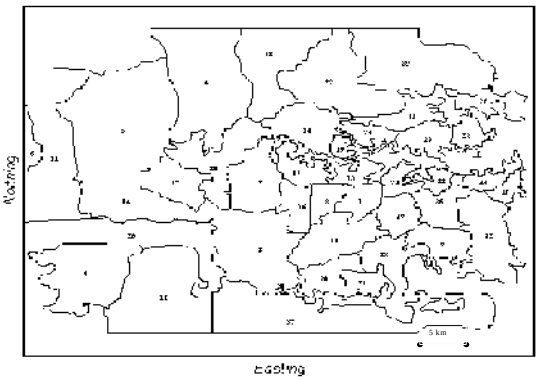

Figure 3. Sydney LGA Boundaries and Zoning System

Dissimilarity index is applied further to confirm the results obtained from the Lorenz curve. Based on the latest census data and the average change in both urban form and travel pattern variables over time, a Z-score is calculated in order to identify outliers or zones that have an extreme value. To facilitate a visual inspection, a scatter-plot for this Z-score is developed.

RESULTS AND DISCUSSION

Following the changes in the distribution of residential workers and employment location over time, the relative jobs and housing distance has also changed. In order to measure this change at the metropolitan level, the dispersal index based on Brotchie (1996) is calculated. At the LGA levels, the jobs-housing balance is measured based on the ratio of residential workers to jobs. The scatter-plot of Z-score is also given to identify extreme values. The accessibility to jobs is calculated based on Hansen's accessibility index for all transportation modes and stratified further for car, bus and train. The Lorenz curve is drawn to evaluate the equality of accessibility to jobs across Sydney over time for each transportation mode.

Dispersal Index

Dispersal index is a measure of the relative dispersion of jobs to housing. Table 1 shows the average jobs and housing distance from the CBD in Sydney and the dispersal index over the 35-year period from 1961 to 1996. The difference between the average housing distance and the average job distance from the CBD is also presented in Table 1. It is identified that although the location of housing on the average is further away from the CBD compared to the location of jobs, the average job distance from the CBD has increased at a greater rate than the average housing distance. This is shown by the change in the difference value which is closer to zero. When the difference is zero, it is an indication that, on average, the distance of jobs and housing from the CBD is equal. The dispersal index further indicates that the value has moved toward unity over time. The dispersal index of 1 indicates that the average job distance from the CBD is the same as the average housing distance. It is clearly shown that as the dispersal index approaches unity, jobs are decentralized at a faster rate than housing.

Table 1. Dispersal Index for Sydney (1961-1996)

Year	Average job distance from CBD (km)	Average housing distance from CBD (km)	Difference (km)	Dispersal Index (DI)
1961	10.88	16.93	6.05	0.642
1966	12.50	18.56	6.06	0.674
1971	13.71	19.76	6.05	0.694
1976	15.29	21.02	5.73	0.727
1981	16.06	22.28	6.22	0.721
1986	16.92	23.02	6.10	0.735
1991	17.78	23.75	5.97	0.749
1996	18.11	23.98	5.87	0.755

Jobs-Housing Balance

Ratio of residential workers to jobs is used to measure the job and housing balance for each of the 38 LGAs in Sydney. LGAs with ratio of 1 indicates that the balance or similar number of workers and jobs are available in that LGA. A ratio lower than 1 and closer to zero indicates that more jobs are available than residential workers. A ratio above 1 shows that there are more workers available than jobs. The lower the ratio, the more people are expected to work locally. On the other hand, the higher the ratio, more people will try to find jobs in the other zones or LGAs. Figure 4 shows the ratio of workers to jobs for 38 LGAs in Sydney by increasing distance from the CBD over the 35-year period from 1961 to 1996. It can be seen that there is no clear trend towards an increase or a decrease in the worker to job ratio by increasing the distance from the CBD. However, several LGAs located close to the CBD tend to have a lower value. In terms of the changes over time, the middle and outer ring LGAs tend to experience a higher decrease compared to the inner ring.

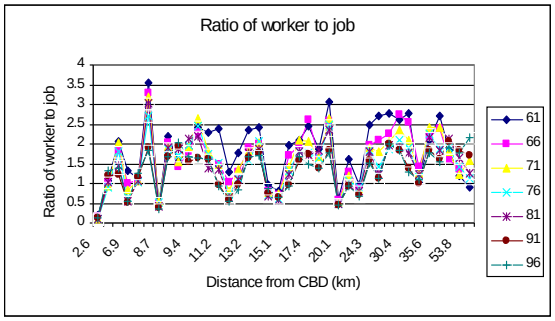

Figure 4 Ratio of Residential Workers to Jobs and Distance from the CBD in Sydney (1961-1996)

Using scatter plot of Z-score, a visual inspection can be done to identify outliers and clusters of zones as given in Figure 5. From the four quadrants in Figure 4.16, the upper right quadrant indicates the cluster of zones with high values based on 1996 census data and they have a high increase in their ratio of residential workers to jobs over time. Zones in the lower left quadrant are those with a low ratio and low increase or a decreasing trend in their ratio of workers to jobs over time. The upper left quadrant indicates a

cluster of zones with a low ratio but they have a high increase in their ratio over time whilst the lower right quadrant is for zones that have a high ratio in 1996 but a decreasing trend in their ratio over time.

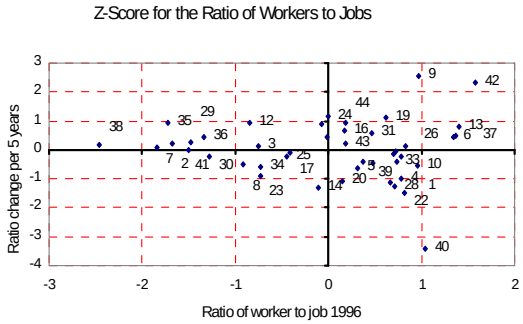

Figure 5. Scatter-plot of Z-score for the Ratio of Residential Workers to Jobs in Sydney

Observations on the horizontal axis indicate that only the Sydney CBD (38) has a ratio beyond two standard deviations lower than the mean value: relatively low numbers of residential workers living in the Sydney CBD; and a high number of jobs available. Wollondilly (42), Drummoyne (13), Sutherland (37) and the Blue Mountains (6) are identified as having a high ratio in 1996 (close to two standard deviations), which indicates that a high number of residents live in these LGAs with a relatively low number of local jobs available. Observations on the vertical axis indicate that Wollondilly (42) and Camden (9) continuously experienced increases in their residential workers to jobs ratio beyond two standard deviations of the mean on the positive side. On the other hand, Waverley (40) had a relatively high ratio in 1996, but it experienced a decreasing trend in its ratio over time, which is over three standard deviations lower than the mean.

Accessibility to Jobs

Accessibility to jobs is calculated based on Hansen's accessibility index. Figure 6 shows the job accessibility in Sydney by increasing LGA distance from the CBD over a 35-year period from 1961 to 1996. Accessibility to jobs tends to decrease by increasing the distance from the CBD. The Sydney LGA has the highest accessibility to jobs, about 179,933 in 1961. It reached 180,938 in 1996. Mosman has the lowest accessibility in the inner ring about 60,682 in 1961 and up to 84,537 in 1996. On average for the inner ring LGAs, the accessibility to jobs has increased from 90,706 in 1961 to 103,641 in 1966, followed by an unstable figure and it reached 110,216 in 1996. The average increase in the accessibility to jobs for the inner ring LGAs is about 2,787 per 5 year or 557 per year.

LGAs has increased at a much steeper rate than that in the inner and middle rings as a result of job decentralization. On average, the accessibility to jobs in the outer ring has increased significantly from 26,812 in 1961 to 46,497 in 1996 with a rate of increase of 2,812 per 5 year or 562 per year – very similar to the inner ring that has the advantage of centrality.

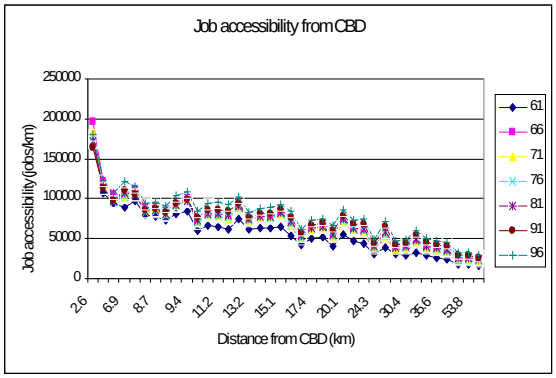

Figure 6. Accessibility to Jobs and Distance from the CBD in Sydney (1961-1996)

Scatter-plot of Z-Score for accessibility to jobs by car shown in Figure 7 provides a visual presentation of the accessibility to jobs by car for each LGA in Sydney in 1996 (horizontal axis) and the average change in the accessibility to jobs by car per 5 years during 1981-1996 period (vertical axis). The four quadrants indicate cluster of zones into four groups. The LGAs clustered in the upper right quadrant are those with relatively high

accessibility to jobs by car compared to the metropolitan average in 1996 with a high increase in their accessibility to jobs by car over time. The upper left quadrant is for LGAs with relatively low accessibility to jobs by car in 1996 but which experience a high increase in their accessibility to jobs by car over time. The lower left quadrant indicates LGAs that have low accessibility to jobs by car in 1996 with a decreasing trend over time. The lower right quadrant shows LGAs with relatively high accessibility to jobs by car in 1996 but which experience a decreasing trend over time.

The accessibility to jobs by car of the 44 LGAs in Sydney are predominantly within two standard deviations of the mean for both in terms of the accessibility to jobs by car in 1996 and the average change per 5 years during the 1981-1996 period. South Sydney (35) and Sydney CBD (38) have relatively high accessibility to jobs by car in 1996 at almost two standard deviations higher than the mean.

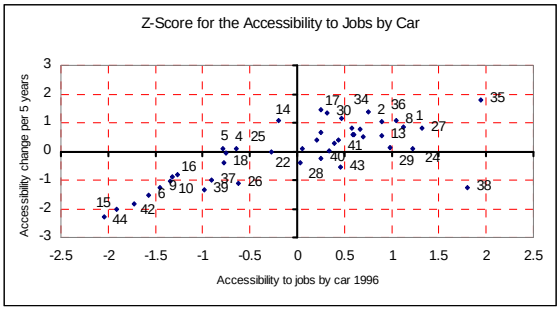

Figure 7. Scatter-plot of Z-score for Accessibility to Jobs by Car in Sydney

However, the Sydney CBD experiences a decreasing trend in its accessibility to jobs by car over time whilst South Sydney continues to experience an increase in its accessibility to jobs by car over time. Wyong (44) and Gosford (15) are identified as having relatively low accessibility to jobs by car in 1996 with a decreasing trend over time at about two standard deviations from the mean.

Figure 8 further show the equality of accessibility to job distribution by car over time. Accessibility to jobs by car across Sydney was more equally distributed in 1981 than that in 1991 and 1996. The accessibility to jobs by car in 1996 is slightly closer to the diagonal line than in the 1991 distribution, which indicates the accessibility to jobs by car in 1996 is slightly more equally distributed than that in 1991.

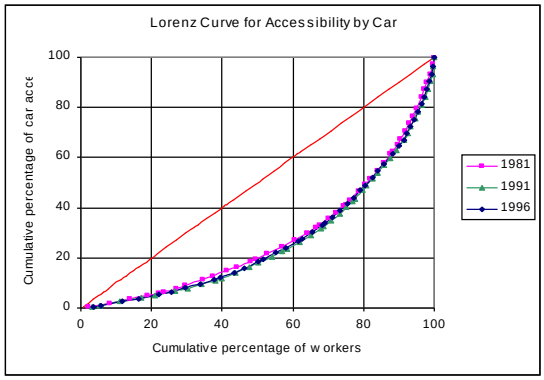

Figure 8. Lorenz Curve for the Accessibility to Jobs by Car in Sydney (1981-1996)

Mean Trip Length by Car

The trip length by car for Sydney in 2011 is predicted by extrapolation techniques. Figure 9 shows the projected trip length by car for 44 LGAs in Sydney for the year 2011 by increasing LGA distance from the CBD. It is predicted that, generally, the inner ring LGAs will experience significant increases in their trip length by car and the LGAs in the middle ring will also experience increases but at a lower rate than that of the inner ring. Several outer ring LGAs are predicted to have relatively stable trip lengths as the results of continuing employment decentralization whilst the others are predicted to have a relatively high increase in their trip length by car. Averaged across the metropolitan area, the mean trip length has increased consistently over time from 14.55 km in 1981 to 15.6 km and 16.0 km in 1991 and 1996, respectively. It is predicted that if this existing trend continues into the future, the mean trip length by car will increase to 17.5 km in 2011 or about 20.5 percent

above its 1981 value (or 9 percent higher than its 1996 value).

The increasing size of a city expanding towards the outer areas might produce longer trips by private car in particular when jobs-skill mismatch is experienced. When the employment moves to the outer areas, people living in the inner and middle ring who can not find their jobs locally, will try to find job opportunities that are available in the outer areas and travel longer distance by car. As the inter-zonal distance between the outer ring LGAs is quite long, residents in several LGAs will travel longer to reach their job destination.

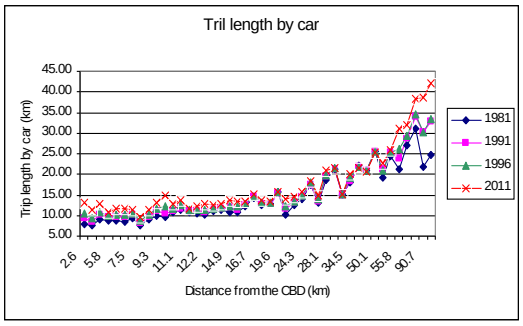

Figure 9. Projection of the Mean Trip Length by Car in Sydney in 2011

CONCLUSIONS

The results indicated that urban form variables vary across the Sydney study area. They have changed over time although several LGAs were identified as experiencing a relatively stable value. Both housing and employment have moved away from the CBD towards the outer areas. The increasing number of job opportunities in the outer areas was expected to reduce the trip length of the residents. However, the findings indicate that only a few outer ring LGAs experienced slightly decreasing trip lengths whilst others experienced a dramatic increase. This is an indication that several LGAs in the outer ring benefited by the decentralization of employment whilst others did not benefit as shown by the increasing trip lengths for commuters. Decentralization of both residential workers and employment was followed by an increasing use of car. Because the employment location in the outer ring is much easier to reach by car, this leads to an increasing car dependence by residents. The radial form of the public transportation network was originally designed to take residents to the CBD destination. Increasing suburb to suburb travel can not be served well by a radial form of public transportation. If the decentralization trend continues into the future without a change to the public transportation service, it is expected that the proportion using car will increase by about 12.7 percent of the 1981 share. The mean trip length by car is predicted to increase by about 20.5 percent from its 1981 value. This finding indicates that the change in the relative jobs-housing location was followed by a change in travel patterns.

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