# ANALYSIS OF PREFERENCE FUNCTION BY CAR IN THE CITY OF SYDNEY, AUSTRALIA

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**Abstract:** One important aspect in the sustainable transportation target is the reduction in vehicle kilometres of travel (VKT) by car. The use of private car is one major contributor of environmental deterioration in Sydney. It is essential to understand the journey-to-work travel behaviour by car. One of the method that can be used to study this travel behaviour is preference function. Using journey-to-work (JTW) Census data over a 35-year period from 1961 to 1996 in Sydney, this paper applies preference functions to study the journey-to-work commuting preferences by car. Descriptive statistics and analysis of variance are applied to evaluate the trends in the slope preferences over time. Moran's *I* statistic of spatial association is used to study the spatial distribution of preference functions, and the pattern of interactions between zones, to assess the level of interaction and to test their statistical significance. The results indicated that the mean slope preference by car has increased over time showing an increasing preference of residents towards distance maximization for traveling to work by car. The slope preferences by car for the inner and middle ring residents are relatively stable over time whilst the outer ring residents (beyond 20 km from the CBD) experienced a dramatic increase. Mostly, the zonal slope preferences by car in Sydney in 1996 were within one standard deviations of the mean. Only Parramatta (30) was found to have a value of over two standard deviations of the mean on the maximization side. It is clearly shown from these results that when increasing job opportunities are available in the surrounding zones, residents tend travel longer to reach job opportunities available in the other zones, in particular, in the case of job-skill mismatch. Therefore, it is not surprising that a dramatic increase in preference for longer trips has been experienced by outer ring residents in Sydney where job decentralization continues to occur over time.

Keywords: preference function, travel behaviour, private car.

# ANALISIS FUNGSI KEINGINAN PERJALANAN DENGAN KENDARAAN PRIBADI DI KOTA SYDNEY, AUSTRALIA

**Abstrak:** Salah satu aspek penting dalam target sistem transportasi berkelanjutan adalah penurunan kendaraan-kilometer. Penggunaan kendaraan pribadi adalah salah satu faktor yang memberikan kontribusi terhadap penurunan kualitas lingkungan di Kota Sydney. Pemahaman terhadap perilaku perjalanan dengan kendaraan pribadi merupakan suatu hal yang penting. Salah satu metode yang dapat digunakan adalah fungsi keinginan (*preference function*). Dengan menggunakan data perjalanan kerja selama 35 tahun dari 1961 sampai 1996 di Kota Sydney, paper ini mengaplikasikan fungsi keinginan untuk mengkaji perilaku perjalanan kerja dengan moda kendaraan pribadi. Statistik deskriptif dan analisis varian digunakan untuk mengkaji distribusi spasial dari fungsi keinginan, interaksi antar zona, tingkat interaksi dan menguji tingkat signifikansinya. Hasil studi menunjukkan bahwa nilai rata-rata slope fungsi keinginan telah meningkat dari waktu ke waktu yang menunjukkan kecenderungan ke arah maksimalisasi jarak perjalanan kerja dengan kendaraan pribadi. Slope fungsi keinginan untuk daerah lingkar dalam dan tengah kota adalah relatif stabil, sedangkan daerah lingkar luar kota (melebihi 20 km dari pusat kegiatan kota) mengalami peningkatan tajam. Sebagian besar zona di Kota Sydney memiliki nilai dibawah satu

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standar deviasi (SD). Hanya Parramatta ditemukan memiliki nilai melebihi dua SD. Kondisi ini memperlihatkan dengan jelas bahwa bila kesempatan kerja tersedia disekitar suatu zona, penduduk cenderung menempuh jarak perjalanan yang lebih jauh untuk mencari pekerjaan di zona sekitarnya, khususnya bila terdapat ketidaksesuaian antara keahlian dan pekerjaan. Oleh karena itu, bukanlah hal yang mengejutkan dimana peningkatan dramatis dari fungsi keinginan terhadap perjalanan yang lebih jauh telah dialami oleh penduduk yang tinggal disekitar lingkar luar Kota Sydney, dimana desentralisasi terjadi dari waktu ke waktu.

Kata kunci: fungsi keinginan, perilaku perjalanan, kendaraan pribadi.

## INTRODUCTION

In urban areas, increased sprawl and automobile dependence has been criticized as having a negative impact on transportation efficiency and environmental quality. OECD (1996) stated that these patterns of automobile dependence are not sustainable from both economical and environmental perspective. The UK Royal Commission on Environmental Pollution (1994) reported that road traffic has caused adverse impacts on air quality, noise, community severance, amenity, natural resources and global warming. Such problems are more acute in the US and Australia where low-density and sprawling development pattern to the outer area has increased car dependence (Newman and Kenworthy, 1999).

ECMT (1995) reported that the car ownership has increased everywhere with USA has the highest level where 58 percent of households own two or more cars and 20 percent have three or more without a clear sign of saturation. Car ownership per capita has been increasing at 2.7 percent p.a. in OECD countries since 1970. Transport is a major consumer of oil and the only sector with the fastest growing consumer. On the other hand, the world's oil resources are finite.

There are several alternative solutions proposed by researchers to reduce urban travel such as through high occupancy vehicle systems (HOV), intelligent transport system (ITS), improvement in technology, increasing fuel tax and revisiting urban form policy. According to McRobert (1997), High Occupancy Vehicle Systems, such as ride-sharing, transit lanes and Intelligent Vehicle Highway Systems contribute only a little on the reduction of greenhouse gas emissions in urban areas. It is difficult to achieve the desired response via fuel tax. Some put faith in technology fixes such as fuel efficiency cars and alternative fuels to address these problems. However, Replogie (1990) argued that these improvements threaten to be outpaced by growth in total automobile use and traffic congestion crisis. 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. Accordingly, understanding the link between urban form and travel pattern is the interest of this study.

Using journey-to-work (JTW) Census data over a 35-year period from 1961 to 1996 in Sydney, this paper applies preference functions to study the journey-to-work commuting preferences by car.

Descriptive statistics and analysis of variance are applied to evaluate the trends in the slope preferences over time. Moran's *I* statistic of spatial association is used to study the spatial distribution of preference functions, and the pattern of interactions between zones, to assess the level of interaction and to test their statistical significance.

## LITERATURE REVIEW

Preference function is an aggregate of individual travel behavioral responses by a zonal grouping given a particular opportunity surface distribution of activities surrounding those travelers (Paez, *et al*., 2001). Operationally, a journey-to-work preference function is the relationship between the proportion of travelers from a designated origin zone who reach their workplace destination zones, given that they have passed a certain proportion of the total metropolitan jobs. To derive such functions information is contained in O-D matrices. Proportion of zonal totals and metropolitan totals are used for standardization purposes, rather than absolute numbers, to facilitate comparison of the shape of preference functions across origin zones within a city, across different cities, and within the same city over time. Conceptually, the raw preference function is simply the inverse of Stouffer's intervening opportunity theory that relates the proportion of migrants (travelers) *continuing* given reaching various proportion of the opportunities reached – or more technically-correct the *l*-factor parameter in the intervening opportunities model of trip distribution (Ruiter, 1969).

Stouffer's hypothesis formed the basis of operational models of trip distribution in some early land-use and transportation studies in the United States of America (for example, the Chicago Area Transportation Study during the late 1950s), and is expressed as:

$$P(dv)=(1-P(v)f(v))dv \qquad (1)$$

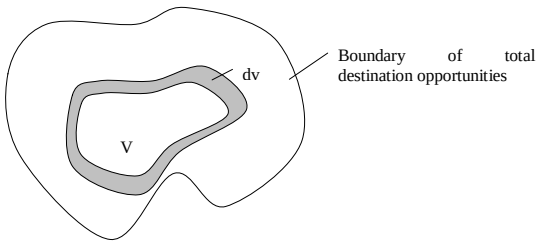
Where:

P(dv) : probability of locating within the dv opportunities, P(dv) = dp;

P(v) : probability of having found a location within the v opportunities;

1-P(v) : probability of having found a location within the v opportunities; and

f(v).dv : probability of finding a suitable location within the dv opportunities given that a suitable location has not already been found.




The term f(v) is often called the *l* parameter, or calibration parameter. It is the ordinate of a probability density function for finding a suitable location given that a location has not already been found. So, equation (1) may be rewritten as:

$$dP = (1-P).\, l\, .\, dv \qquad (2)$$

If *l* is a constant and the initial conditions are P=0 when v=0 then:

$$lv = -Ln(1-P) \qquad (3)$$

Hence,

$$P = 1 - e^{-lv} \qquad (4)$$

Whereas equation (4) is used to derive trip distribution models, equation (3) is the mathematical expression for the preference function. The relationship between the cumulative total number of opportunities passed, v, and the natural logarithm of the cumulative total number of opportunities taken, Ln (1-P), is assumed to be linear. One of the issues was calibrating the *l*-factor parameter (Ruiter, 1967), and whether there was a break of slope to justify different parameters for "short" and "long" trips. There is little evidence in the literature

that operational models based on Stouffer's hypothesis were developed, and transportation engineering practice generally favored the gravity model as a mechanism for forecasting future trip O-D tables.

## METHODOLOGY

The study area is the Sydney Statistical Division defined by the Australian Bureau of Census, comprising 40 local government areas (LGA) in the County of Cumberland plus the four adjacent areas to Wollondilly, the Blue Mountains, Gosford and Wyong. Figure 1 shows a diagrammatic map of Sydney region. The 44 LGAs were grouped into three regional rings: inner, middle and outer ring.

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. This research draws on tabulations provided by the NSW Department of Transport, Transport Data Centre (TDC).

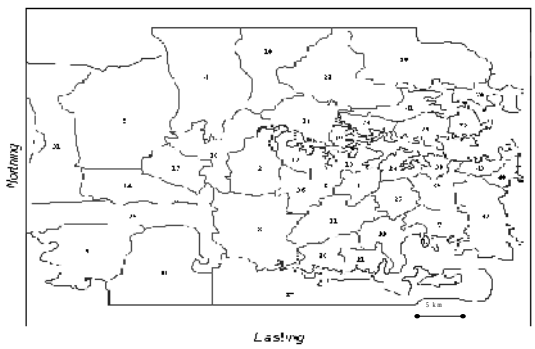



**Figure 1. Sydney LGA Boundaries and Zoning System**

Descriptive statistics and analysis of variance are applied to evaluate the trends in the slope preferences over time. Moran's *I* statistic of spatial association is used to study the spatial distribution of preference functions, and the pattern of interactions between zones, to assess the level of interaction and to test their statistical significance. Scatter-plot decomposition of the spatial statistic assists analyzing interaction patterns, and to detect spatial outliers (zones). Identifying particular planning needs is one outcome of this methodology.

The local government areas (LGAs) performances are evaluated using scatter-plot based on the total amount of travel by car (measured in persons.kilometers) and the change in the slope preferences by car. Based on this scatter-plot, the critical LGAs with a low (unsustainable) performance are thereby identified. Historical patterns of development and the policies associated with them that may help to explain low (or high) performance is beyond the scope of this paper.

## RESULTS AND DISCUSSION

### Slope Preference by Car in Sydney

Table 1 is a summary of descriptive statistics of the slope for commuting preferences by car in Sydney over a 15-year period from 1981 to 1996. The absolute value of the mean slope preference by car increased by 0.013 over this period from 0.195 in 1981 to 0.208 in 1996. Wyong had the lowest value of the slope preference by car (absolute) and it increased constantly more than doubling in value from 0.033 in 1981 to 0.076 in 1996. Parramatta had the highest value of the slope (absolute) and it also increased consistently from 0.274 in 1981 to 0.303 in 1996.

**Table 1. Summary of Descriptive Statistics of the Slope Preferences by Car in Sydney (1981-1996)**

| Statistics | 1981 | 1991 | 1996 |
|---|---|---|---|
| Mean | -0.195 | -0.203 | -0.208 |
| Standard deviation | 0.055 | 0.048 | 0.047 |
| Minimum | -0.274 | -0.295 | -0.303 |
| Maximum | -0.033 | -0.070 | -0.076 |
| Range | 0.240 | 0.225 | 0.227 |

Figure 2 shows the slope preferences by car for 44 LGAs in Sydney by increasing LGA distances from the CBD over a 15-year period from 1981 to 1996. The slope preferences by car for the inner and middle ring residents (within 20 km of the CBD) are relatively stable. In contrast, the outer ring residents, beyond 20 km from the CBD mainly experienced a significant increase. Several LGAs show drastic changes. South Sydney experienced the highest increase in the inner ring in absolute terms (about 0.015 per 5 years from 0.227 in 1981 to 0.250 in 1996). Several extreme cases were found in the outer ring: Gosford experienced a high increase, about 0.016 per 5 years from 0.034 in 1981 to 0.084 in 1996; Camden experienced increases at the rate 0.016 per 5 years from 0.105 in 1981 to 0.153 in 1996 and Wyong experienced increases, although at a lesser rate (about 0.014 per 5 years from 0.033 in 1981 to 0.076 in 1996). The findings indicate that decentralization of employment towards the outer areas increased the behavioral preferences by car of residents in these outer areas towards longer trips, or a maximizing behavioral response. Therefore, future distribution of employment needs to be carefully located, because decentralization of employment is not associated with minimizing distance behavior for travel to work by car for outer ring residents.

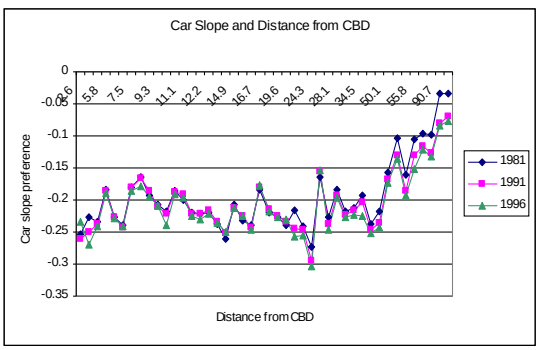



**Figure 2. Slope Preference by Car in Sydney by Increasing Distance from the CBD (1981-1996)**

**Spatial Analysis of Commuting Preferences by Car**

Figure 3 shows the Moran's scatterplot for the slope preferences by car in Sydney in 1996. To facilitate interpretation, the variables have been normalized with respect to the mean (PF) and standard deviation (s). The PF is used as a spatial variable and analyzed using Moran's *I*. The result indicates a positive spatial autocorrelation where similar values are found at neighboring locations with $I = 0.562$. The Z-statistic, $Z(I) = 11.729$ shows that the pattern deviates significantly from a random pattern where the zones interact with others with similar preference.

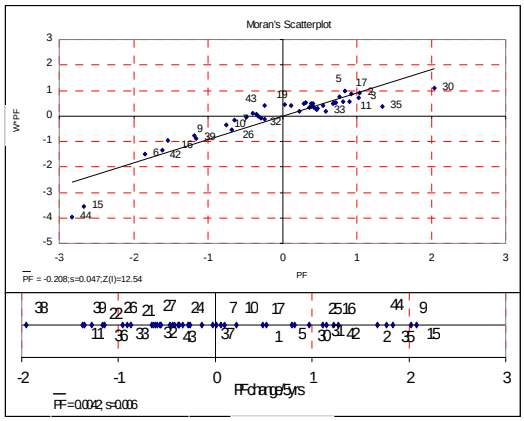



**Figure 3. Moran's Scatter-plot for Slope Preferences by Car (1996) Using O-D Matrix**

Figure 3 shows that the zonal slope preferences by car in Sydney in 1996 are predominantly within one standard deviations of the mean. However, Parramatta (30) is found to have a value of the slope preference by car that is more than two standard deviations higher than the mean (on horizontal axis of Figure 3) despite the fact that it has a relatively high concentration of employment and is regarded as the second CBD in Sydney. On the other hand, Wyong (44) and Gosford (15) have values that are more than two standard deviations lower than the mean (negative side of the horizontal axis). The relative isolation of Wyong and Gosford from the other LGAs has shaped

residents preference for shorter travel and many find their jobs locally.

At the bottom part of Figure 3, a scatter-plot of the average change in the slope preference by car per 5 years is presented. It is shown that the LGAs in Sydney mainly experienced changes in the slope preferences by car with values within one standard deviation of the mean. However two extreme cases were identified. Although having a low slope preference by car (absolute), Gosford (15) experienced an increase in the absolute value of the slope preference by car per 5 years and was over two standard deviations higher than the mean. Similarly, Camden (9) also experienced a high increase in its slope preference (over two standard deviations higher than the mean value). This indicates an increasing trend for both Gosford and Camden residents to travel longer distances (distance maximization) to reach their work places. The location of Gosford is relatively isolated from the other LGAs. Increasing numbers of job opportunities available in this LGA and surrounding LGAs over time as a result of decentralization, have changed the behavioral response of residents towards distance maximization, where an increasing number of people are employed in the other surrounding LGAs. Residents in the Sydney LGA (38) are found to have preference towards shorter trips and its value is close to two standard deviations lower than the mean.

Figure 4 further shows Moran's scatter-plot for the zonal slope preference by car considering destination-origin (D-O) matrix or demand side. Zones with minimization preferences tend to attract trips from zones with similar preferences whilst zones with maximization preferences tend to attract zones also with maximization preferences. The result of Moran's $I$ ($I$ = 0.710) indicates the existence of positive spatial autocorrelation which is statistically significant (Z(I) = 15.21).

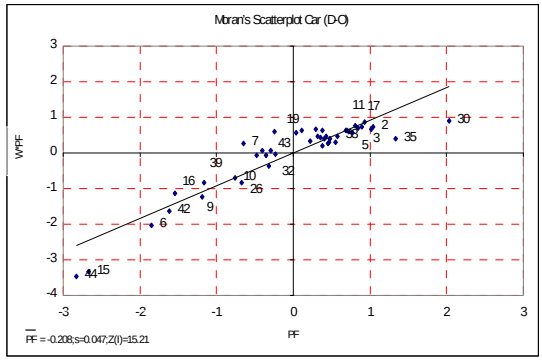



**Figure 4. Moran's Scatter-plot for Slope Preference by Car (1996) Using D-O Matrix**

## Evaluation of LGA Performances

In order to identify the critical LGA locations in Sydney, the performance of the LGAs are evaluated based on Z-score for the total amount of travel by car for 1996 data and the change in the slope preference by car per 5 years from 1981 to 1996. The LGAs with low performance are those with a high total amount of travel by car and a high increase in their slope preference by car towards distance maximization. Figure 5 shows the scatter-plot of Z-score for the total amount of travel by car and the change in slope preference by car per 5 years. The variables are normalized with respect to the mean total amount of travel by car (x-axis) and mean absolute slope preference by car change per 5 years (y-axis).

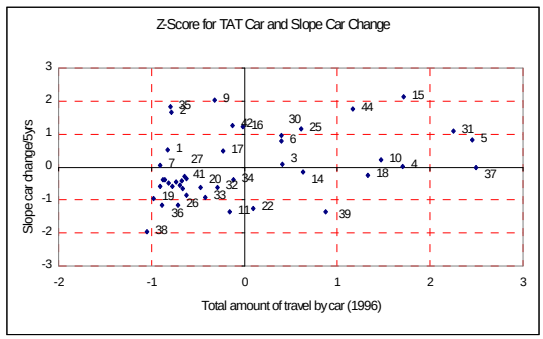



**Figure 5. Scatter-plot of Z-score for Total Amount of Travel by Car and the Change in Slope Preference by Car in Sydney**

Three extreme cases are identified where Sutherland (37), Blacktown (5) and Penrith (31) are found to have a total amount of travel by car that is over two standard deviations higher than the mean. LGAs located on this positive side of the vertical axis are classified into LGAs with high change in the slope preference towards distance maximization.

## Commuting Preferences and Trip Length

Figure 6 shows the regression analysis between the slope preference by car and mean trip length by car for 44 LGAs in Sydney using 1996 JTW census data. The negative association indicates that LGAs with higher (absolute) slope preference by car tend to have lower mean trip length. The slope preference by car explains about 45 percent of variation in mean trip length.

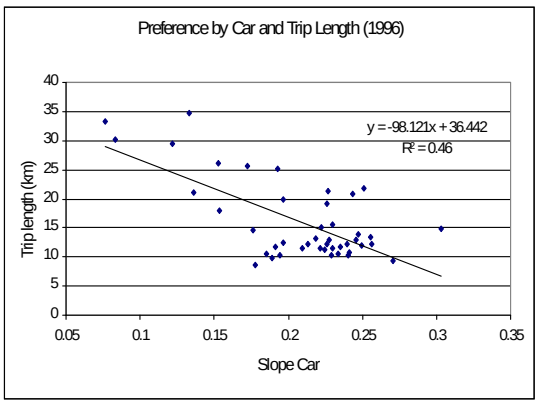



**Figure 6. Slope Preference by Car and Trip Length by Car, Sydney, 1996**

Figure 7 shows the result of regression analysis between the change in the slope preference by car and the change in the mean trip length by car. The absolute change between the 1981 census and the 1996 census data is used here. The change in the slope preference by car is positively associated with the change in the mean trip length by car. LGAs that experience an increase in their slope preference by car (absolute) during the 1981-1996 period tend to experience an increase in their mean trip length during this period. An increase in the slope preference by 0.01 is associated with an increase in the mean trip length by 0.58 km. Variation in the change in the slope preference by car explains 30 percent of variation in the change in the mean trip length by car.

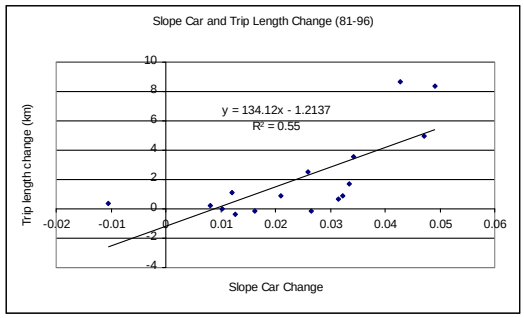



**Figure 7. Slope Preference by Car and Trip Length by Car Change, Sydney, 1981-1996**

## CONCLUSION

The mean slope preference by car has increased over time showing an increasing preference of residents towards distance maximization for traveling to work by car. The slope preferences by car for the inner and middle ring residents are relatively stable over time whilst the outer ring residents (beyond 20 km from the CBD) experienced a dramatic increase. A significant positive spatial association was identified for both supply and demand sides. Zones with a preference towards long trips, on average, tend to travel to zones that also prefer longer trips. On the other hand, zones with a preference towards shorter trips, travel to zones that also have preference for shorter trips. Mostly, the zonal slope preferences by car in Sydney in 1996 were within one standard deviations of the mean. Only Parramatta (30) was found to have a value of over two standard deviations of the mean on the maximization side. It is clearly shown from the results that when increasing job opportunities are available in the surrounding zones, residents tend travel longer to reach job opportunities available in the other zones, in particular, in the case of job-skill mismatch.

Therefore, it is not surprising that a dramatic increase in preference for longer trips has been experienced by outer ring residents in Sydney where job decentralization continues to occur over time.

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