COMMUTING PREFERENCES BY BUS AND TRAIN IN SYDNEY AUSTRALIA

Putu Alit Suthanaya
Department of Civil Engineering
Faculty of Engineering
Udayana University
Bukit Jimbaran – Bali,
suthanaya@rocketmail.com

Abstract

In order to achieve sustainable transportation target, one of the transportation policy commonly adopted is to increase the use of public transport, for example, bus and train. It is, therefore, important to study the commuting behavior by bus and train of residents. Two techniques were applied to study commuting behavior, i.e. preference functions and Moran's I spatial statistic. The commuting preference by bus was found to move towards distance maximization over time. Unlike decreasing trend for the slope preferences by bus by increasing LGA distances from the CBD, there is no clear increasing or decreasing trend for the slope preferences by train. Similar to bus, the slope preferences by train are relatively stable over time. A significant positive spatial association was identified for the slope preferences by bus for both O-D and D-O matrices, however the spatial variation in the slope preferences by train was found to be random.

Keywords: commuting preferences, spatial association, preference function

Abstrak

Untuk mencapai target transportasi berkelanjutan, suatu kebijakan transportasi yang biasa diterapkan adalah meningkatkan penggunaan angkutan umum, misalnya, bis dan kereta api. Oleh karena perilaku perjalanan komuter yang dilakukan oleh penduduk yang menggunakan bis dan kereta api penting untuk dipelajari. Dua teknik diterapkan untuk mempelajari perilaku komuter, yaitu fungsi preferensi dan statistika spasial Moran I. Preferensi komuter dengan bis ditemukan bergerak ke arah maksimalisasi jarak dari waktu ke waktu. Tidak seperti pola penurunan untuk preferensi dengan bis dengan meningkatnya jarak LGA dari CBD, tidak terdapat pola yang jelas preferensi dengan menggunakan kereta api. Mirip dengan bis, preferensi dengan kereta api relatif stabil dari waktu ke waktu. Sebuah hubungan spasial positif yang signifikan duketahui untuk preferensi dengan bis untuk matriks-matriks OD dan DO matriks, namun variasi spasial dalam preferensi dengan kereta api bersifat acak.

Kata kunci: preferensi perjalanan komuter, asosiasi spasial, fungsi preferensi

INTRODUCTION

OECD (1996) stated that the patterns of automobile dependence experienced by cities in the world are not sustainable from both economical and environmental perspective. The negative effects of traffic include lost time and productivity, vehicular accidents, greenhouse gas emissions, deteriorating air quality, and associated risks on respiratory and cardiovascular health (Dahl, 2005; WHO, 2005). 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). Improving the quality of urban public transport is one of many strategies proposed to improve mobility options (BIC, 2003) and to address car dependence and the urban congestion, environmental sustainability, and global warming concerns associated with car dependence (Hamilton, 2006). However, according to Holmgren et.al (2008), local public transport development in Sweden, like in many other European countries, has been on the decline. A similar pattern is found in Great Britain. Mulley and Nelson (2009) stated that an ideal world public transport would be as convenient as private transport, suggesting that ‘all public transport should be demand responsive.’ Therefore, it is important to understand factors influencing commuting preferences by public transport.

Commuting has been the focus of a variety of multidisciplinary research studies (Horner 2004). Most research using aggregate commuting data has focused on metro areas as the spatial units of analysis. Crane (2000) summarizes some of the recent work that analyzes the effects of neighborhood types. Gordon et.al (2004) found that transit commuting impacts and neighborhood type are interdependent. In similar study, Montis et.al (2010) also argued that similar commuting networks emerge in similar geographical settings. Historical analyses of the changing nature of the commuting preferences by public transport are relatively rare and concentrate mainly on alterations in the relationship between home and workplace, and the changing structure of the city. Historical study of the journey to work in Toronto during 1900-40 suggests that the decentralization of employment opportunities tended to shorten the journey to work for residents who lived in suburban locations (Harris and Bloomfield, 1997).

The journey to work is one of the most commonly experienced forms of every-day travel, encompassing almost all transport modes, and making a substantial contribution to urban traffic congestion (Pooley and Turnbull, 2000). The weakness in most of the journey-to-work trip studies was the use of a static approach (i.e. the analysis was done at one point in time). It is essential to understand how commuting behavior contributes to either longer or shorter journeys. One way of doing this is to examine the commuting preferences of residents, and to establish how they have changed over time since the redistribution of employment and residential workers. Preference functions can be used to evaluate the behavioral response change of the residents following the change in urban form over time at the zonal level (Black et.al, 2002; Black and Suthanaya, 2002). Using journey-to-work (JTW) Census data over a 15-year period from 1981 to 1996 in Sydney, this paper applies preference functions to study the journey-to-work commuting preferences by bus and train. 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.

Unlike the raw preference functions these are the transformed preference functions with negative gradients, as in the above formula, where small (absolute) values of parameter a are associated with a preference for shorter trips and large (absolute) values are associated with a preference for longer trips, everything else being equal. The slope of these empirically determined preference functions tells us much about travel behavior as a pure response to opportunities, and not to transport impedance (distance, time or cost) as in the gravity model of trip distribution.

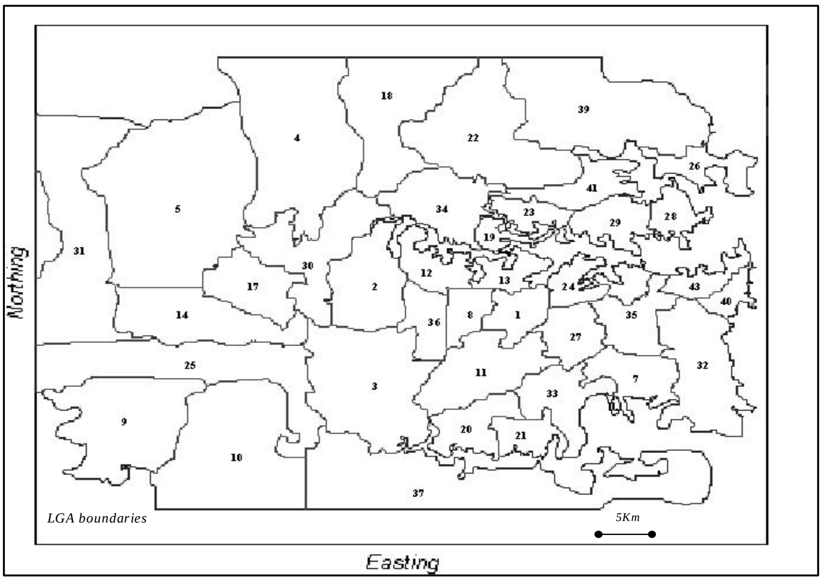
Study Area

Sydney Metropolitan Region is selected as a case study area. The configuration of the 44 LGAs is shown in Figure 1. This analysis uses time-series journey-to-work (JTW) census data over a 15 years period from 1981 to 1996 for the analyses of preference function by bus and train. Inter-zonal (LGA) distances over the road network were provided by the NSW State Transport Study Group, now the Transport Data Centre. Preference function is applied to study the journey-to-work commuting preferences by bus and train. 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.

RESULTS AND DISCUSSIONS

Commuting Preferences by Bus

Table 1 summaries descriptive statistics of the slope preferences by bus in Sydney over a 15-year period, from 1981 to 1996. The descriptive statistics reveal that the absolute value of the slope preferences by bus has increased from 0.150 in 1981 to 0.169 in 1996. This indicates that the behavioral preference of residents for commuting by bus has moved toward longer trips or distance maximizing trends.



Source: NSW Transport Data Center (2002)

Note:
Zone 1(Ashfield), 2(Auburn), 3(Bankstown), 4(Baulkham Hills), 5(Blacktown), 6(Blue Mountain), 7(Botany), 8(Burwood), 9(Camden), 10(Campbelltown), 11(Canterbury), 12(Concord), 13(Drummoyne), 14(Fairfield), 15(Gosford), 16(Hawkesbury), 17(Holroyd), 18(Hornsby), 19(Hunter's Hill), 20(Hurstville), 21(Kogarah), 22(Ku-ring-gai), 23(Lane cove), 24(Leichardt), 25(Liverpool), 26(Manly), 27(Marrickville), 28(Mosman), 29(North Sydney), 30(Parramatta), 31(Penrith), 32(Randwick), 33(Rockdale), 34(Ryde), 35(South Sydney), 36(Strathfield), 37(Sutherrland), 38(Sydney), 39(Warringah), 40(Waverley), 41(Willoughby), 42(Wollondilly), 43(Woollahra) and 44(Wyong). Zones 15 (Gosford), 16 (Hawkesburry), 42 (Wollondilly) and 44 (Wyong) not in map.

Figure 1 Sydney Zoning System

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

Statistics	1981	1991	1996
Mean	-0.150	-0.160	-0.169
Standard deviation	0.089	0.101	0.120
Minimum	-0.292	-0.470	-0.676
Maximum	-0.009	-0.025	-0.028
Range	0.283	0.446	0.647

By increasing LGA distances from the CBD, Figure 2 shows that the absolute value of the slope preferences by bus tend to decrease. This indicates that LGAs located further away from the CBD have preferences towards shorter trips to work by bus. Residents in the outer ring tend to use bus for local or short distance commuting trips only. On average in the outer ring, the slope preference by bus has increased by about 0.091 per 5 years from 0.022 in 1981 to 0.296 in 1996. On the other hand, residents in the inner ring tend to use bus for traveling to work for longer distance commuter trips. The slopes of preferences by bus are relatively more stable over time regardless of the LGA distance from the CBD. However, several extreme cases were identified. A substantial increase in the absolute value of the slope preferences by bus is experienced in the Sydney LGA (about 0.145 per 5 years from 0.240 in 1981 to 0.676 in 1996).

Commuting Preferences by Train

The summary of descriptive statistics for the slope preferences by train in Sydney given in Table 2 indicate that the mean absolute value has increased by about 0.005 per 5 years from 0.260 in 1981 to 0.278 in 1991. It then decreased slightly to 0.275 in 1996. The lowest absolute value tends to decrease over time from 0.149 in 1981 to 0.164 in 1996. On the other hand, the highest absolute value increased during the 1981-1991 period from 0.981 in 1981 to 1.141 in 1991 and then decreased to 1.017 in 1996. The mean value is much closer to the lowest absolute value, indicating the skewed distribution of the slope preferences by train data.

The slope preferences by train for 44 LGAs in Sydney by increasing LGA distances from the CBD is presented in Figure 2. Unlike the decreasing trend in the absolute slope value for bus, there is no clear increasing or decreasing trend for the absolute slope value for train. The slope preferences by train are mainly stable for all LGAs in Sydney over time. However, Sydney and South Sydney experienced a significant change and their slopes are very different when compared to the other LGAs. Sydney had a slope preferences of 0.981 in 1981, which is much higher than the mean slope value of 0.260.

By comparing commuting preferences by bus and train, it is found that the use of bus is mainly preferred for short distance trip to work whilst train is for long distance trips. The mean slope preference (absolute) for bus increased consistently whilst the mean slope for train (absolute) is unstable. This indicates an increasing trend in residents' preference towards longer trips to reach their job destination by using bus. Residents' preferences in traveling to work by train are unstable with only a slight move towards shorter trips in the 1991-1996 period.

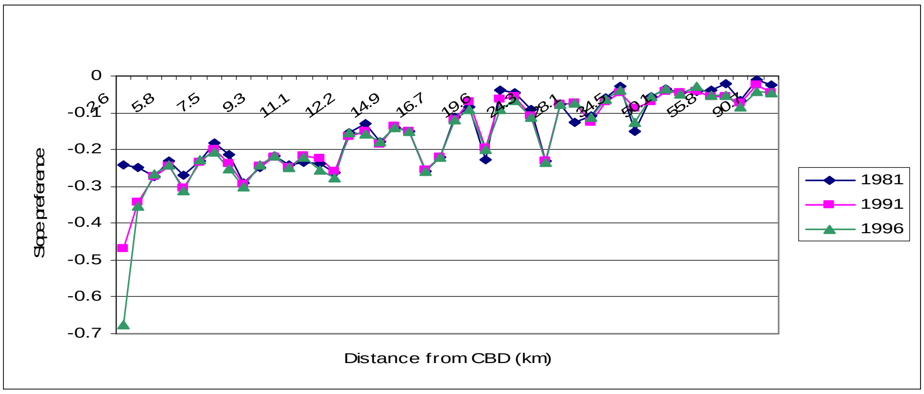


Figure 2 Slope Preference by Bus in Sydney by Increasing LGA Distance from the CBD (1981-1996)

Table 2 Summary of Descriptive Statistics of the Slope Preferences by Train in Sydney (1981-1996)

Statistics	1981	1991	1996
Mean	-0.260	-0.278	-0.275
Standard deviation	0.124	0.147	0.129
Minimum	-0.981	-1.141	-1.017
Maximum	-0.149	-0.148	-0.164
Range	0.832	0.993	0.853

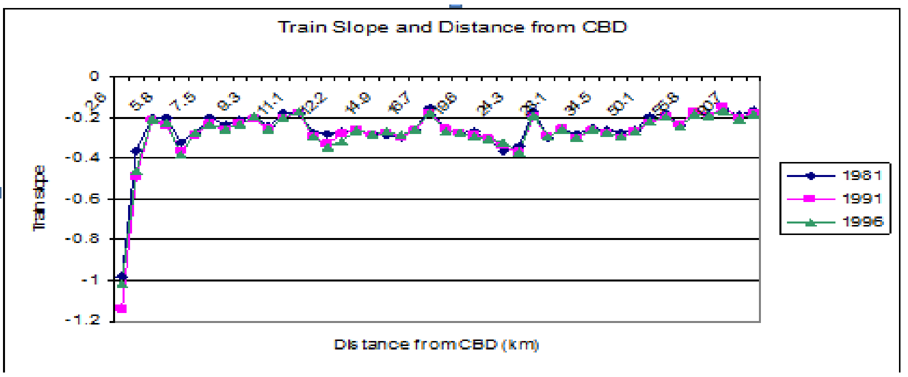


Figure 3 Slope Preference by Train in Sydney by Increasing Distance from the CBD (1981-1996)

Spatial Analysis of the Commuting Preferences by Bus

Figure 4 shows the Moran's scatter-plot for the distribution of zonal slope preferences by bus in Sydney in 1996. The variation of zonal slope preferences by bus is not very extreme as most of the slope preferences are within one standard deviation and only a few zones are beyond one standard deviation on either the minimization or the maximization side. However, one extreme case is identified where Sydney (38) has slope preferences beyond four standard deviations on the maximization side. Moran's statistic of I = 1.250, indicates the existence of positive spatial autocorrelation. Further significance testing with Z-statistic, Z(I) = 10.39 indicates the significance of this positive spatial autocorrelation. The residents in the zones with high slope (preferences towards longer trips) tend to interact with zones having high values (absolute) of slope preferences. On the other hand, the residents in zones with low absolute slope preferences tend to travel to zones also with low absolute slope or zones with preferences towards distance minimization. Scatter-plot of the average change in the slope preferences by bus per 5 year shown at the bottom of Figure 4 indicates that the values are mainly within one standard deviation from the mean. Only one extreme case was identified where Sydney (38) experienced an increase in the slope preference by bus of over six standard deviations above the mean value. This indicates an increasing preference of residents in Sydney LGA to use bus for traveling to work for longer distances over time given already having a high absolute value. Figure 5 explains further that an extensive bus service in the inner areas (within 11 km from the CBD), enable people living in the inner ring to travel longer by bus to reach their work place, in particular, to the CBD destination (for example in the figure, Sydney (38) and Leichardt (24)). Residents living in Sydney (38) tend to travel longer by bus to reach their work place given the high intensity of bus services in this LGA. People living in Penrith (31) tend to take the bus mainly for local and relatively short trips, whilst car dominates long distance trips. The proportion of workers using bus in the outer areas is much lower than that in the inner and middle areas because of the lack of reliable bus services. Low density and scattered jobs locations make it much more convenient for these outer ring residents to travel by car.

By considering the destination-origin (D-O) matrix, a positive spatial association is also experienced as shown in Moran's scatter-plot (Figure 6). Zones with preference towards distance maximization tend to attract trips from zones which also show maximization preferences. On the other hand, zones with preference towards distance minimization tend to attract trips from zones with similar preferences. This positive spatial association is confirmed further from Moran's *I* statistic with *I* = 0.589 and Z(I) = 4.90.

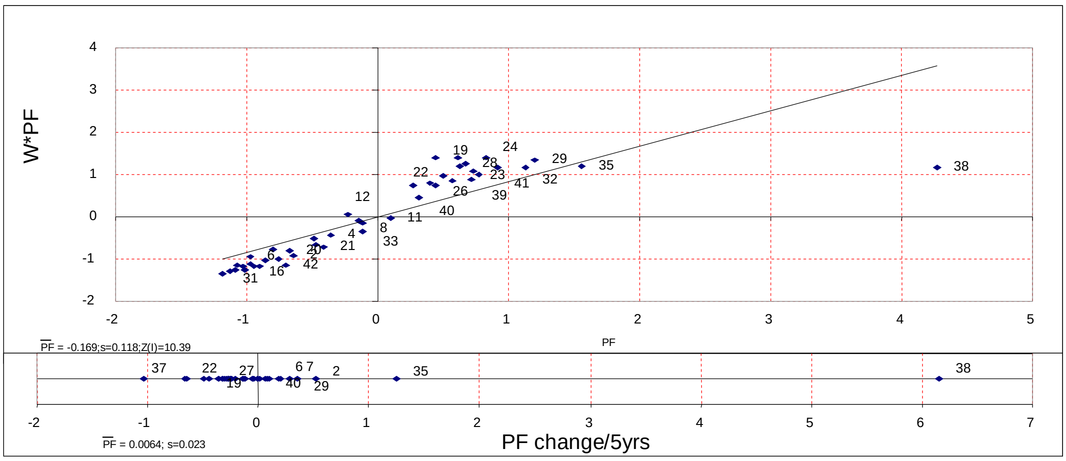


Figure 4 Moran's Scatter-plot for Slope Preferences by Bus

Spatial Analysis of Commuting Preferences by Train

In the case of commuting preferences by train, Figure 7 shows Moran's scatter-plot for 44 zones in Sydney in 1996. Visual inspection of Figure 7 indicates that the slope preferences by train tend to be randomly distributed. A slightly negative spatial association is identified from the regression line (mainly caused by the existence of outlier of zone 38, SydneyCBD). A negative and low *I* value of –0.020 with Z(I) = -0.154 further confirms the tendency of random spatial distribution. Unlike the slope preferences for bus where similar values tend to cluster, a cluster of dissimilar values is experienced here (based on *I* value). Zone 38 (Sydney) has the slope preference over five standard deviations higher than the mean on the maximization side. By excluding this zone, a visual inspection of Figure 7 indicates the existence of positive spatial association. It is clearly shown that residents in the zones with preferences towards longer trips tend to travel to the zones that have similar preferences. Residents living in the zones having preferences towards distance minimization also tend to travel to zones with preferences for shorter trips.

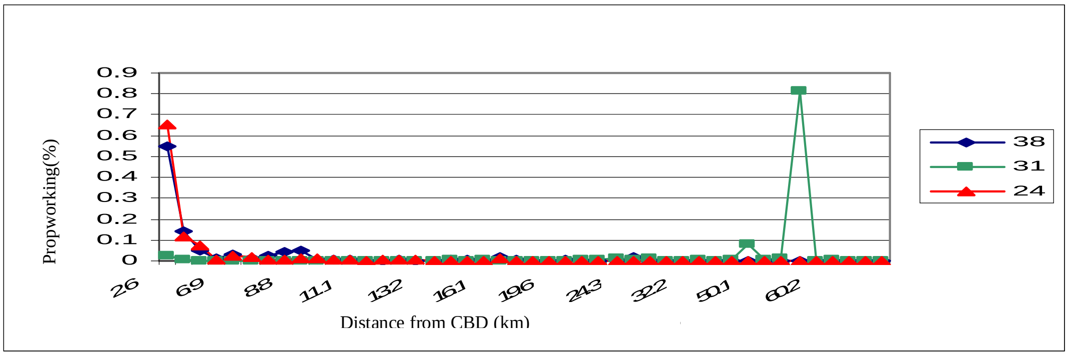


Figure 5 Proportion of Residents Working by Bus by Increasing Distance from the CBD

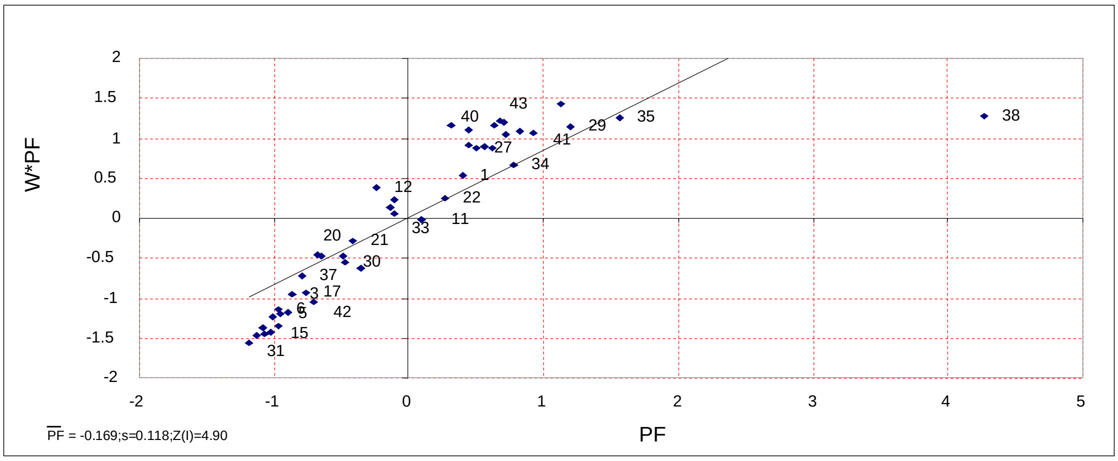


Figure 6 Moran's Scatter-plot for Slope Preferences by Bus Using D-O Matrix

From the scatter-plot of the average change in the slope preferences by train per 5 years given at the bottom of Figure 7, it can be seen that the values are mainly within one standard deviation from the mean. Three zones have values between one and two standard deviations of the mean at the maximization side and two zones at the minimization side. Willoughby (41) has value over two standard deviations higher than the mean. South Sydney (35) experienced changes and is over three standard deviations higher than the mean. At the minimization side, Bankstown (3) has value over two standard deviations lower than the mean. This indicates that South Sydney and Willoughby residents experienced a dramatic increase in their preference towards distance maximization for traveling to work by train compared to the other zones. On the other hand, Bankstown (3) residents experience change in their preference for shorter trips in reaching their work destination by train (by over two standard deviations lower than the mean). A similar result is found when the destination-origin (D-O) matrix, or demand side, is considered, as shown from Moran's scatter-plot (Figure 8). A random spatial interaction is identified as supported by the Moran's I statistic (I = 0.050 and Z(I) = 0.387). Interaction tends to occur between zones with dissimilar values when seen from the demand side.

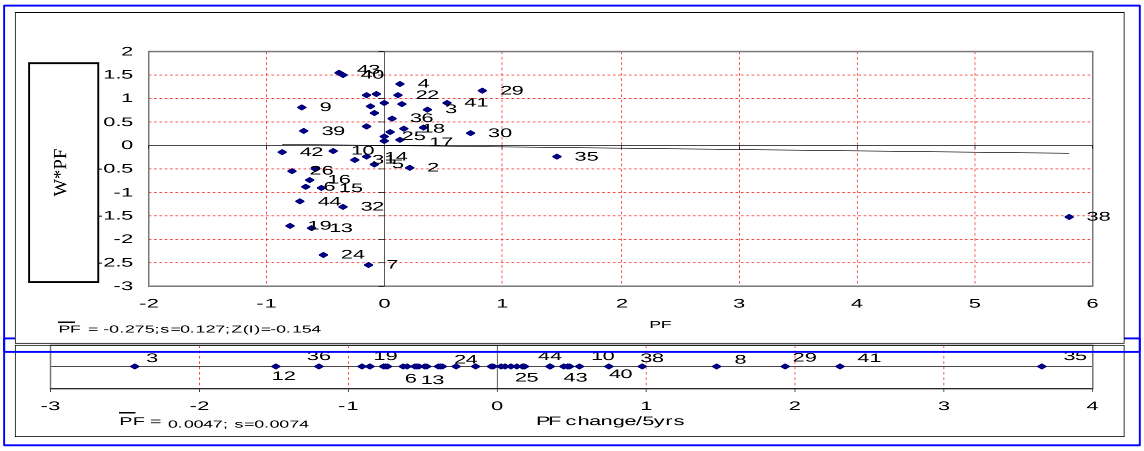


Figure 7 Moran's Scatter-plot for Slope Preferences by Train Using O-D Matrix

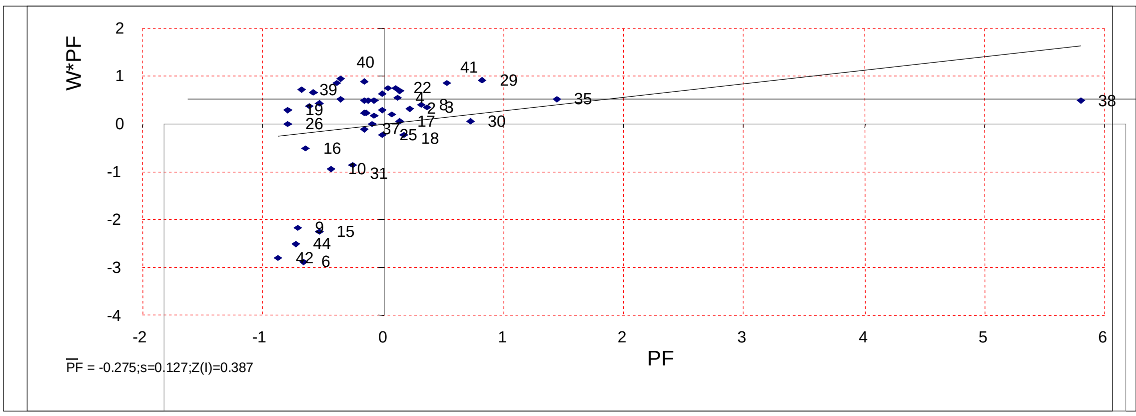


Figure 8 Moran's Scatter-plot for Slope Preferences by Train (1996) Using D-O Matrix

CONCLUSIONS

The results of preference functions analyses indicated that the mean slope preference by train was significantly higher by about 0.102 than bus. This indicated that bus was preferred for shorter distance trips whilst train was preferred for longer distance trips to work. The commuting preference by bus was found to move towards distance maximization over time. By increasing distances from the CBD, the absolute values of slope preferences by bus tend to decrease. This showed that the outer ring residents tend to use bus for shorter distance trips. For the commuting preferences by train, the mean absolute value of the slope was unstable over time. Unlike decreasing trend for the slope preferences by bus by increasing LGA distances from the CBD, there was no clear increasing or decreasing trend for the slope preferences by train. A significant positive spatial association was identified for the slope preferences by bus. One extreme case was identified where Sydney (38) had slope preferences beyond four standard deviations on the maximization side. Scatter-plot of the average change in the slope preferences by bus per 5 years further indicates that the Sydney LGA had an extreme value. This indicated an increasing preference of residents in the Sydney LGA to use bus for traveling to work for longer distances over time. Unlike the existence of positive spatial association for both slope preferences by bus, the spatial variation in the slope preferences by train was found to be random. The scatter-plot of the average change in the slope preferences by train further indicated that the values were mostly within one standard deviation of the mean. Three zones had values between one and two standard deviations of the mean at the maximization side and two zones at the minimization side. Willoughby (41) had a value which was over two standard deviations higher than the mean. South Sydney (35) experienced change which was over three standard deviations higher than the mean. On the minimization side, Bankstown (3) had a value over two standard deviations lower than the mean. This indicated that South Sydney and Willoughby residents experienced a dramatic increase in their preference towards distance maximization for traveling to work by train compared to the other zones. On the other hand, Bankstown residents experienced a change in their preference for shorter trips in reaching their work destination by train.

REFERENCES

Bus Industry Confederation. 2003. *Towards More Sustainable Cities*. Building a Public Transport Culture Submission by the Bus Industry Confederation to the House of Representatives Standing Committee on Environment and Heritage's Inquiry into Sustainable Cities 2025.

Black, J. and Suthanaya, P. 2002. *VKT Generated by Local Government Areas, Sydney, 1961-1996, and Projections to 2011*. 25th Australian Transport Research Forum (ATRF). Canberra.

Black, J., Paez, A. and Suthanaya, P. 2002. *Sustainable Urban Transportation: Performance Indicators and Some Analytical Approaches*. American Society of Civil Engineers. Journal of Urban Planning and Development, Special Issue: Advances in Urban Planning Methodologies I: Recent Advances, 128 (4): 184-209.

Crane, R. 2000. *The Influence of Urban Form on Travel*. An Interpretive Review, Journal of Planning Literature, 15,1: 3-23.

Dahl, R. 2005. *Heavy Traffic Ahead*. Environmental Health Perspectives, 113: 239–245.

Gordon, P., Lee, B., Moore, J.E., Richardson, H.W., and Williamson, C. 2004. *Neighborhood Attributes and Commuting Behavior: Transit Choice*. Metrans Project 03-20. Final Report unpublished. School of Policy, Planning, and Development. Los Angeles: University of Southern California.

Hamilton, B. A. 2006. *Study of Successful Congestion Management Approaches and the Role of Charging, Taxes, Levies and Infrastructure and Service Pricing in Travel Demand Management*. Council of Australian Governments.

Harris, R. and Bloomfield, A. 1997. *The Impact of Industrial Decentralization on the Gendered Journey to Work, 1900-1940*. Economic Geography, 73: 94-117.

Holmgren, J., Jansson, J. O., and Ljungberg, A. 2008. *Public transport in towns – Inevitably on the decline?*. Research in Transportation Economics, 23: 65–74.

Horner, M. 2004. *Spatial dimensions of urban commuting: A review of major issues and their implications for future geographic research*. The Professional Geographer, 56 (2): 160–173.

Montis, A. D., Chessa, A., Campagna, M., Caschili, S., and Deplano, G. 2010. *Modeling Commuting Systems Through A Complex Network Analysis: A Study of the Italian Islands of Sardinia and Sicily*. Journal of Transport and Land Use, 3 (4): 39-55.

Mulley, C., and Nelson, D. 2009. *Flexible transport services: A new market opportunity for public transport*. Research in Transportation Economics, 25: 39–45.

Newman, P. and Kenworthy, J. 1999. *Sustainability and Cities: Overcoming Automobile Dependence*. Washington, D.C: Island Press.

New South Wales Transport Data Center. 2002. *Journey to Work Data*. Sydney: New South Wales Department of Transport.

Organisation for Economic Co-operation and Development. 1996. *Towards Sustainable Transportation*. Conference Proceedings. British Columbia.

Pooley, C. G. and Turnbull, J. 2000. *Modal choice and modal change: the journey to work in Britain since 1890*. Journal of Transport Geography, 8: 11-24.

World Health Organization. 2005. *Health Effects of Transport-Related Air Pollution*. Copenhagen.