

The Effects of Polycentric Development on Commuting Patterns in Metropolitan Areas

Dong Lin, Andrew Allan, Jianqiang Cui and Ralph McLaughlin

Urban and Regional Planning, School of Natural and Built Environments, University of South Australia, Adelaide

Emails: Dong.Lin@mymail.unisa.edu.au; Andrew.Allan@unisa.edu.au; Jianqiang.Cui@mymail.unisa.edu.au; Ralph.McLaughlin@unisa.edu.au

1. Introduction

The study of how employment decentralization in polycentric metropolitan areas affects patterns of commuting has created many intense debates in the research areas of geography and urban planning based on empirical studies in developed countries of North America, Europe, Oceania as well as developing countries of Asia during last two decades (Gordon & Wong 1985; Cervero & Landis 1991; Giuliano & Small 1993; Naess & Sandberg 1996; Gordon & Richardson 1997; Aguilera 2005; Parolin 2005; Alpkokin et al. 2008; Guth, Holz-Rau & Maciolek 2009; Veneri 2010; Zhao, Lu & Roo 2011). A major reason for the intensity of these debates is the question of whether the evolution of a polycentric spatial structure in mega cities can provide more opportunities to enhance spatial matches between job and housing location selections of employees who live in suburban areas. Accordingly, employment decentralization and polycentric development would improve commuting patterns by shortening individual commuting distances and time. This paper will review empirical studies in relation to this crucially important research topic. An understanding of how urban spatial structure influences commuting patterns can improve the management and strategic planning of cities to ensure that urban spatial structure optimises the aggregate travel behaviour of urban commuters.

2. Monocentric and Polycentric Cities

According to various patterns of spatial organization and employment layout, urban spatial structure can be divided into monocentric and polycentric city models (Ingram 1997; Bertaud 2003; Ding 2007). The monocentric city as conceptualized by Alonso (1964), was the first formal model of urban spatial structure. It directly showed that cities had a unique centre, often termed the Central Business District (CBD). The monocentric city has been the model most widely used to analyze the spatial organization of cities (Bertaud 2003). Based on the hypothesis of monocentric city, Alonso

(1964), Muth (1969), and Mills and Song (1979) worked on the application of density gradients to urban areas.

In the mid to latter half of the 20th century, employment began to disperse, with the proportion of jobs in the centre decreasing over time and most new growth in employment being located outside of the CBD of mega cities (Meyer & Gómez-Ibáñez 1981). It had become obvious over the years that the structure of many metropolitan areas diverged from the monocentric model and that many daily trips expanded in clusters over a wide area outside the original CBD (Bertaud 2003). Many cities evolved from a monocentric spatial structure into a polycentric city model.

From the 1980s onwards, theories and models have been developed by scholars in the fields of geography, urban and regional planning as well as economics to analyse polycentric urban growth based on the concept of the polycentric city (Yue, Liu & Fan 2010). Some scholars thought that the early post-war ideas on polycentricity related to the 'freeway stage' of suburbanisation of the North American metropolis (Muller 1981; Knox & McCarthy 2005). Cities developed expansive suburban areas where growth rates of population sometimes exceeded those of their centre (Romein 2005). Muller (1981) proposed a concept of the Multi-centred Metropolis, which showed that some suburbs had transformed into increasingly independent and self sufficient urban entities beyond the older central city. These urban entities not only hold a rising share of the population of metropolises, but also accommodated increasing major economic activities, employment, and social, educational, cultural and entertainment services. Additionally, Garreau (1991) put forward an idea of 'edge cities', a model of polycentric spatial structure usually located at major highway interchanges, to describe new suburban cities with office buildings and huge commercial infrastructures. Fujita, Krugman and Venables (2001) developed a theoretical framework to describe the evolution of polycentric structure that had resulted from centripetal forces and the agglomeration of economic relationships between firms. Anas and Kim (1996) established a computable general equilibrium model to demonstrate the emergence of urban sub-centres resulted from multiple equilibria. Hall (1999) supposed that the Polycentric City focuses on the location of business and envisaged a new polycentric urban form emerging in many contemporary cities. The Polycentric City included six main elements: a traditional business core; a secondary business core; a tertiary business core or inner-city edge city; an outer edge city; outermost edge cities; and specialised concentrations. Further, Bertaud described the relationship and evolvement of monocentric and polycentric city as follows:

'As they grow in size, the original monocentric structure of large metropolises tends with time to dissolve progressively into a polycentric structure. The CBD loses its primacy, and clusters of activities generating trips are spreading within the built-up area. Large cities are not born polycentric; they may evolve in that direction. Monocentric and polycentric cities are animals from the same specie observed at a different time during their evolutionary process' (Bertaud 2003, p. 6).

3. Metropolitan Spatial Structure and Patterns of Commuting

There are some scholars that have explored the connection between urban spatial structure and patterns of commuting. In both developed and developing countries, the decentralization of urban employment and dispersed urban spatial structure has profound implications for people's commuting patterns (Ingram 1997). Shen (2000) argued that the main ingredients of an urban spatial structure are the people's spatial distribution, socioeconomic opportunities' spatial distribution, especially employment, and the people's commuting behaviour that links to opportunities.

In a monocentric city, since there is a highly concentrated employment centre and residents generally live in suburb, there would be high commuting flows on radial routes into the centre because the urban commuting would have many origins for work trips but a concentrated destination. In reality, a polycentric city functions in a similar manner to a monocentric city – people are attracted by jobs from all over the city. But the commuting patterns are different (Bertaud 2003). There are two commuting models of polycentric city. One model is that the city has some sub-centres of employment of a similar scale and in such a kind of polycentric city, each sub-centre generates trips from all over the city. The characteristics of commuting present a wide dispersion of origins and destinations, appearing almost random. Another model is that there are also different sub-centres of employment but one sub-centre is more concentrated and stronger than others. The urban commuting flows would be composite of both random and radial patterns (Ingram 1997; Ding 2007; Bertaud 2003; Bertaud 2009). Accordingly, various models of spatial structure have diverse influences affecting people's patterns of commuting particularly in trip duration, distance as well as modal choice.

4. Monocentric or Polycentric?

In the past twenty years, the issue of how employment decentralization and polycentric development in metropolitan areas has affected commuting patterns has led to many robust and continuing debates. Some scholars thought that a development pattern of highly concentrated employment centres in metropolitan areas is not as good as a dispersed and polycentric model for urban development. Suburbanization, as the main mechanism, has successfully reduced traffic congestion. It has altered roadway demand to routes with less congestion and away from central areas. With industry moves to the suburbs, the labour force has tended to follow, which has allowed many employees to enjoy reduced commuting times and less traffic congestion in traditional city centres (Gordon, Kumar & Richardson 1989; Giuliano & Small 1993; Gordon & Richardson 1997).

Previous studies based on analysis of detailed data of metropolitan travel from NPTS (Nationwide Personal Transportation Studies of U.S., 1977 and 1983-1984) and a commuting questionnaire included in the American Housing Surveys (1985) had showed that in monocentric or dense cities located in north east of the U.S such as Chicago and Baltimore, the commuting trips and time required tended to be longer as city size increased. But in some western coastal cities such as Los Angeles, the expansion of city size did not lead to an increase in trip distance. They also found that the trip distances of western cities were shorter than they were for north east cities in the morning peak time despite these cities' sizes being similar (Gordon & Wong 1985). There is another distinct difference in comparing commuting times for dense cities (New York, Chicago, Baltimore) with dispersed cities (Dallas, Phoenix, San Diego) - people who live in the downtown of a dense city spend 25% to 30% more time commuting (Gordon, Richardson & Jun 1991). Some scholars thought that dense cities result in much longer commuting times than decentralized cities (Gordon, Richardson & Jun 1991; Gordon & Richardson 1997). Hence, they believed that this is an important point because it suggests that polycentric or dispersed metropolitan structures in western cities of the U.S. are especially suited to shortening trip distance and time. The reasons are that urban sprawl and polycentric development offer more and varied opportunities for faster commutes through changes of housing or employment, the relocation of enterprise, or the choice of uncongested roadways (Gordon, Richardson & Jun 1991).

There are some other studies that also showed that employment decentralization and polycentric development in metropolitan areas can create the potential for shorter commuting (Giuliano 1991; Giuliano & Small 1993). Giuliano used 1980 Los Angeles region commute data to support her view that workers with jobs in Los Angeles's downtown have longer commuting distance (13.9 Miles) than workers with jobs outside downtown and other sub-centres (Giuliano 1991). In other research

by Giuliano investigating 1980 journey to work data of Los Angeles, it shows that the polycentric structure of development, along with the decentralization of employment outside centres altogether, creates the potential for shorter workers' commutes who work in downtown Los Angeles (Giuliano & Small 1993).

There are also some similar case studies from European and Asian cities. One recent empirically based study from German urban regions based on data on commuter flows (German Census 1987 and German Social Security Statistics 2007) provides somewhat support for polycentric development. In their research they found that the polycentric city tends to be more travel-efficient when compared with a monocentric city. A polycentric city's commuting volumes are much higher than that of a monocentric city. The finding of their research shows that average distance of commuters in polycentric cities of Stuttgart (13.5 km) and Frankfurt (16.4 km) is lower than that experienced in the monocentric cities of Munich (19.0 km) and Hamburg (20.8 km) in 2007 (Guth, Holz-Rau & Maciolek 2009). There is another case study in Istanbul based on available data from 209 traffic analysis zones which showed that the average commuting time decreased in all the zones due to highway improvements with suburban clustered employment growth (polycentric development) in Istanbul from 1985 to 1997 (Alpkokin et al. 2008).

Some empirical studies from China also certified that polycentric development based on well planned sub-centres and regional policies would be beneficial to workers' commuting patterns. In research based on a household interview survey conducted in Beijing in 2006, Zhao, Lu & Roo (2011) argued that employment decentralization and polycentric development in Beijing would be beneficial to the jobs and housing relationship. Regional policies could impact on commuting patterns via the supply of various types of housing. The appropriate regional policies could be beneficial to polycentric development and control the dispersion of development and then achieve the aim of reducing commuting distances particularly for long distance commuters.

Several researchers have proposed a 'co-location hypothesis', that is, employment dispersion would enhance opportunities of residents and workers to change their housing or jobs locations as well as travel mode in order to avoid the congestion that lengthens commuting distance and travel time (Gordon, Kumar & Richardson 1989; Gordon, Richardson & Jun 1991). Accordingly, dispersion would reduce the phenomenon of urban congestion. One recent study from Italy corresponds with the findings from Gordon et al. It shows that the formation of a sub centre would enhance the

probability of finding a job near the home. This in turn, allows a decrease both in workers' commuting distances and travel times (Veneri 2010).

This contrasts with some empirical studies show that polycentric development, dispersed metropolitan structures and suburbanization barely ameliorate the urban congestion phenomenon in metropolitan areas and indeed, actually increase workers' longer commuting distances and travel times (Cervero & Landis 1991; Levinson & Kumar 1994; Naess & Sandberg 1996; Cervero & Wu 1998; Parolin 2005; Aguilera 2005).

In research on submarket analysis of the San Francisco Bay Area, Cervero and Landis (1991) compared two subgroups of workers depending on whether their housing location at the time of job relocation was located either in the downtown area (i.e. city centre) or a suburb. The first sub group were those workers whose jobs moved from the downtown area but who retained a central city home address. Thus their commuting pattern changed from a central city commute to a downtown to suburb commute. With job relocation, the average commuting distance increased 477% and average trip duration increased by 75%. Another sub group are suburban workers whose housing was relocated to the suburbs. Generally, the results were that average commuting distances almost doubled, and commuting travel times were also much more the same as before. And in further research, Cervero and Wu (1998) adopted two indices namely average one-way commute distance and average one-way commuting durations to examine the relationship between employment centres' growth and workers' commuting patterns during the 1980s. He found that among all 22 employment centres in the San Francisco Bay Area, from 1980 to 1990, average one-way commuting distances rose 12% and average one-way commuting time increased by 5%. These results show that, contrary to the co-location hypothesis, dispersed urban structure has not been related with shorter average commuting distances and time. In another similar study regarding how urban dispersion impact commuting patterns in U.S. metropolitan areas, after analysis detailed personal travel surveys data which were conducted by the Metropolitan Washington Council of Governments, it indicated that metropolitan Washington region's average work to home travel distance had increased from 6.6 miles in 1968 to 8.2 miles in 1988. The researcher thus supposed that the phenomenon of dispersion caused increase of commuting distance (Levinson & Kumar 1994).

Besides U.S. empirical studies, investigation of cities in Europe and the Asia Pacific region have also reached similar conclusions. Research of six companies in Greater Oslo, Norway showed that the distance from downtown Oslo to the workplace independently influenced the work commuting

distance when other variables such as commuter train accessibility stayed constant. The further that companies were away from downtown Oslo, the longer the average commuting distance became. Analysis of data showed that when the distance from a company to downtown Oslo rose from 2 km to 12 km, the average work commuting trip increased from 10.5 km to 12.4 km. This study of the long-term effect of job relocations within Oslo's metropolitan area shows the obvious rise in average commuting trip length of a job location moving to the urban periphery (Naess & Sandberg 1996). A study based on census data of French metropolitan areas (Paris, Lyon and Marseille) in 1990 and 1999 showed that co-location hypothesis only can affect a minority of residents, of whom there were fewer in 1999 than there were in 1990. The majority of workers living in a sub-centre worked outside their sub-centre of living. This phenomenon was even more severe in 1999 than nine years earlier. In other words, the majority of jobs located in sub-centres are occupied by non-residents. Consequently the average distance of commuters increased during the past decade (Aguilera 2005).

Some new evidence to support monocentric city and dense development is also evident from empirically based research in New Zealand and Australia. Research exploring the relationship between urban form and transport in Christchurch, New Zealand via the analysis of journey to work data from 1991 and 2001, showed that average workers' commuting distances increased over time with the decentralisation of employment and residential development, particularly for people who live in low density suburbs. Furthermore, the results suggested that there was increasing spatial mismatch between jobs and housing locations, particularly prominent for residents of the more affluent suburbs in Christchurch (Buchanan et al. 2006). In Sydney Australia, there were similar findings from a case study based on an analysis of journey to work data in 1981 and 2001 (Parolin, 2005). It showed that the average commuting distance to all 28 employment centres in 1981 and 39 employment centres in 2001 in Sydney had increased from 17.93km to 20.66km, a 15.2% increase over two decades. A 10.9% increase in average commuting distance of workers occurred for job locations that were not located within employment centres. Parolin (2005) also concluded that during this period of rapid employment dispersion and polycentric development, it did not appear that Sydney residents selected residential locations in suburbs closer to their job location in terms of the measure of average commuting distance. Their result is consistent with the argument of Cervero et al based on their case study of San Francisco in 1998.

In Asian mega cities, research conducted in Seoul, Korea, Jun (2000) compared the before and after effect of new town construction to examine differences in patterns of commuting for the Seoul metropolitan area. Average commuting trips length of workers who live in new towns became

significantly longer ranging from 12% to 70% from 1990 to 1996. The average commuting trip length of new town dwellers (Bundang) was 18.2 km, whereas that of old town dwellers (Sungnam) was 11.6 km. These results clearly revealed that the construction of a new town in the Seoul metropolitan area has an effect of longer commuting trips.

Bertaud (2003) and Ding (2007) also supported the concept of a monocentric urban structure optimising urban economics because they argue that a monocentric city can maintain a unified labour market by providing the possibility of moving easily along radial roadways from the urban fringe to the centre, which seems to be consistent with the theory of agglomeration economics. By contrast, polycentric spatial structure often leads to labour market fragmentation and would increase distances between workers' housing and job locations.

5. Conclusion

From the views of advocates of polycentric city development, we can see that the urban formation mechanisms of suburbanization and polycentric centres have successfully reduced commuting trips and transport congestion in some mega cities. Polycentric urban structure has altered roadway demand to routes with less congestion and away from the traditional central business district (CBD) core of a metropolitan area. With industry and services dispersing to the suburbs and polycentric centres, the labour force follows, which allows many workers to enjoy less commuting distances and travel times, thereby resulting in reduced congestion in a metropolitan area's CBD.

However, the findings of advocates of monocentric structure as previously discussed, one common and significant viewpoint is that both urban dispersion and polycentric development are associated with employment decentralization, which would easily create a jobs-housing spatial mismatch within a given geographic area. Such a mismatch would lead to increasing trip commuting distances and time in metropolitan areas. Conversely, Giuliano (1991) and Dubin (1991) argued that sub-centres or given geographic areas of a polycentric or a dispersed city provide sufficient housing choices and jobs that are matched in both quantity and quality (when measured by their social-economic characteristics), then these areas could be considered as 'balanced' thereby resulting in workers selecting residential locations as close to their jobs' location as possible. One unknown aspect of this argument is the effect of economic inefficiencies that impede the turnover of housing stock in metropolitan housing markets on labour force mobility, which can vary considerably across nations and even within metropolitan housing markets. Notwithstanding this caution, polycentric urban

development would have the potential to successfully reduce commuting trip distances and time in the metropolitan areas of both developed countries and fast growing developing countries.

In addition to the jobs and housing relationship, some other factors such as mixed land use, residential densities, regional policy as well as improvements of transport infrastructure and services appear to influence commuting patterns in a polycentric city. On one hand, in the dispersed cities of developed countries, mixed land uses and residential densities of sub centres and suburbs play a role in influencing commuting distances. For example, the presence of nearby commercial land uses is associated with short commute trip distances among residents of a mixed land use areas (Cervero 1996). When city grew and dispersed, people living in low density suburban areas had much greater commuting trip distances than people who lived in high density areas. People living in high density areas also had a higher percentage of public transport and bicycle trips than was the situation in low density areas (Buchanan et al. 2006). On the other hand, managed and planned polycentric urban structure whereby urban growth is directed towards dispersed activity centres could potentially reduce commuting trip distances and time in both developed and developing cities (Dieleman, Dijst & Burghouwt 2002; Buliung & Kanaroglou 2006; Zhao, Lu & Roo 2011). In particular, some empirical studies based on cities in fast growing developing countries show that regional policies and improvements of transport in a polycentric city would have an effect on people's commuting trip patterns (Alpkokin et al. 2008; Zhao, Lu & Roo 2011). The argument in this regard, is that commuting trip distances could potentially be substantially reduced due to improvements in transport infrastructure and services that serve the sub centres of polycentric cities. Furthermore, a polycentric city in which all of its centre nodes are networked would provide greater overall metropolitan trip efficiencies through a networked transit infrastructure than could be achieved with a monocentric focused transit network. Crucially, regional policies can also play a significant role in reducing commuting distances via the supply of various types of housing that would be beneficial for optimising the ratio of jobs housing balance.

References

Aguilera, A 2005, 'Growth in Commuting Distances in French Polycentric Metropolitan Areas: Paris, Lyon and Marseille', *Urban Studies*, vol. 42, no. 9, pp. 1537–1547.

Alpkokin, P, Cheung, C, Black, J & Hayashi, Y 2008, 'Dynamics of Clustered Employment Growth and Its Impacts on Commuting Patterns in Rapidly Developing Cities', *Transportation Research Part A: Policy and Practice*, vol. 42, no. 3, pp. 427–444.

- Alonso, W 1964, *Location and Land Use: Toward a General Theory of Land Rent*, Harvard University Press, Cambridge, MA.
- Anas, A & Kim, I 1996, 'General Equilibrium Models of Polycentric Urban Land Use with Endogenous Congestion and Job Agglomeration', *Journal of Urban Economics*, vol. 40, no. 2, pp. 232-256.
- Bertaud, A 2003, *The Spatial Organization of Cities: Deliberate Outcome or Unforeseen Consequence?*, World Development Report 2003: Dynamic Development in a Sustainable World, World Bank.
- Bertaud, A 2009, *Urban Spatial Structures, Mobility and The Environment*, World Bank, Washington DC.
- Buchanan, N, Barnett, R, Kingham, S & Johnston, D 2006, 'The Effect of Urban Growth on Commuting Patterns in Christchurch, New Zealand', *Journal of Transport Geography*, vol. 14, no. 5, pp. 342-354.
- Buliung, RN & Kanaroglou, PS 2006, 'Urban Form and Household Activity-Travel Behavior', *Growth and Change*, vol. 37, no. 2, pp. 172-199.
- Cervero, R & Landis, J 1991, *Suburbanization of Jobs and the Journey to Work*, Department of City and Regional Planning, University of California at Berkeley, Berkeley, CA.
- Cervero, R 1996, 'Mixed Land-Uses and Commuting: Evidence from the American Housing Survey', *Transportation Research Part A: Policy and Practice*, vol. 30, no. 5, pp. 361-377.
- Cervero, R & Wu, K-L 1998, 'Sub-centring and Commuting: Evidence from the San Francisco Bay Area, 1980-90', *Urban Studies*, vol. 35, no. 7, pp. 1059-1076.
- Dieleman, FM, Dijst, M & Burghouwt, G 2002, 'Urban Form and Travel Behaviour: Micro-level Household Attributes and Residential Context', *Urban Studies*, vol. 39, no. 3, pp. 507-527.
- Ding, C 2007, *Urban Spatial Planning: Theory, Method and Practice*, Higher Education Press, Beijing.
- Dubin, R 1991, 'Commuting Patterns and Firm Decentralization', *Land Economics*, vol. 67, no. 1, pp. 15-29.
- Fujita, M, Krugman, PR & Venables, AJ 2001, *The Spatial Economy: Cities, Regions and International Trade*, MIT Press, Cambridge, MA.
- Garreau, J 1991, *Edge City: Life on the New Frontier*, Doubleday, New York.
- Giuliano, G 1991, 'Is Jobs-Housing Balance a Transportation Issue?', *Transportation Research Record*, no. 1305, pp. 305-312.
- Giuliano, G & Small, KA 1993, 'Is the Journey to Work Explained by Urban Structure?', *Urban Studies*, vol. 30, no. 9, pp. 1485-1500.

- Gordon, P & Wong, HL 1985, 'The Costs of Urban Sprawl: Some New Evidence', *Environment and Planning A*, vol. 17, no. 5, pp. 661-666.
- Gordon, P, Kumar, A & Richardson, HW 1989, 'The Influence of Metropolitan Spatial Structure on Commuting Time', *Journal of Urban Economics*, vol. 26, no. 2, pp. 138-151.
- Gordon, P, Richardson, HW & Jun, M-J 1991, 'The Commuting Paradox Evidence from the Top Twenty ', *Journal of the American Planning Association*, vol. 57, no. 4, pp. 416-420.
- Gordon, P & Richardson, HW 1997, 'Are Compact Cities a Desirable Planning Goal?', *Journal of the American Planning Association*, vol. 63, no. 1, pp. 95-106.
- Guth, D, Holz-Rau, C & Maciolek, M 2009, 'Employment Suburbanisation and Commuter Traffic in German City Regions', 9th Swiss Transport Research Conference, Ascona, September 9-11.
- Hall, P 1999, 'The Future of Cities', *Computers, Environment and Urban Systems*, vol. 23, pp. 173-185.
- Ingram, GK 1997, *Patterns of Metropolitan Development: What Have We Learned?*, World Bank - Operations Evaluation Department (OED).
- Jun, M-J 2000, 'Commuting Patterns of New Town Residents in the Seoul Metropolitan Area ', *Journal of the Korean Regional Development Association*, vol. 12, no. 2, pp. 157-170.
- Knox, PL & McCarthy, L 2005, *Urbanization: An Introduction to Urban Geography*, Second edn, Prentice Hall, Englewood Cliffs, NJ.
- Levinson, D & Kumar, A 1994, 'The Rational Locator: Why Travel Times Have Remained Stable', *Journal of the American Planning Association*, vol. 60, no. 3, pp. 319-332.
- Ma, Q, Zhang, W & Wang, X 2004, 'Review on Spatial Structure of The Metropolis Affecting Its Traffic', *Economic Geography*, vol. 24, no. 2, pp. 215-220.
- Meyer, JR & Gómez-Ibáñez, JA 1981, *Autos, Transit, and Cities*, Harvard University Press, Cambridge, MA.
- Mills, ES & Song, B-N 1979, *Urbanization and Urban Problems (Harvard East Asian Monographs)*, Harvard University Press, Cambridge, MA.
- Muller, PO 1981, *Contemporary Suburban America*, Prentice Hall, NJ.
- Muth, RF 1969, *Cities and Housing: The Spatial Pattern of Urban Residential Land Use*, University of Chicago Press, Chicago, IL.
- Naess, P & Sandberg, SL 1996, 'Workplace Location, Modal Split and Energy Use for Commuting Trips', *Urban Studies*, vol. 33, no. 3, pp. 557-580.
- Parolin, B 2005, 'Employment Centres and the Journey to Work in Sydney: 1981-2001', Second State of Australian Cities conference Griffith University, Brisbane, 30 Nov to 2 Dec, pp. 1-15.

Romein, A 2005, 'The Contribution of Leisure and Entertainment to the Evolving Polycentric Urban Network on Regional Scale: Towards a New Research Agenda', The 45th Congress of the European Regional Science Association, Free University Amsterdam, Netherlands, 23-27 August.

Shen, Q 2000, 'Spatial and Social Dimensions of Commuting', *Journal of the American Planning Association*, vol. 66, no. 1, pp. 68-82.

Yue, W, Liu, Y & Fan, P 2010, 'Polycentric Urban Development: the Case of Hangzhou', *Environment and Planning A*, vol. 42, pp. 563-577.

Veneri, P 2010, 'Urban Polycentricity and the Costs of Commuting: Evidence from Italian Metropolitan Areas', *Growth and Change*, vol. 41, no. 3, pp. 403–429.

Zhao, P, Lu, B & Roo, Gd 2011, 'The Impact of Urban Growth on Commuting Patterns in a Restructuring City: Evidence from Beijing', *Papers in Regional Science*, vol. 90, no. 4, pp. 735-754.