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Excess Commuting: A Critical Review

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ABSTRACT *Excess commuting is the additional journey-to-work travel represented by the difference between the actual average commute and the smallest possible average commute, given the spatial configuration of workplace and residential sites. Research on excess commuting has been carried out over the last 20 years since the seminal contribution of Hamilton (1982). The literature has generated much debate and controversy, and the purpose of this review paper is to assess that material critically under three main headings: contextual, methodological and policy-related issues. The key contextual questions relate to the assumptions of transport optimization or cost minimization, socio-economic factors, and how these are linked to urban spatial structure. The methodological issues cover spatial structure, aggregation, time or distance measures, and the boundary problem, whilst the policy-oriented questions relate to the understanding of the effects of taking particular actions, including the behavioural response to policy initiatives.*

Introduction

The original concept of excess commuting is concerned with the difference between the average actual commute and the optimum (or minimum) commute that could occur in a monocentric urban model. This interesting concept has emerged from Hamilton (1982), who questioned whether actual commuting behaviour can be predicted by the classic monocentric model. The main proposition of the monocentric model is that the workers' optimization strategy is reflected by the trade-off between house prices and commuting costs, and it is considered to play an important role in shaping the locations of jobs and housing (Alonso, 1964; Muth, 1969; Mills, 1972). This deep-seated assumption (based in urban economic theory) has been challenged by Hamilton's empirical results showing a large discrepancy between the actual commute and the required commute predicted by the classic monocentric model.[1]

Much of the initial discussion concerning excess commuting has been focused on whether the monocentric model adequately represents the actual metropolitan spatial structure and whether the assumption of the standard urban economic model on commuting behaviour is still applicable in the modern metropolitan

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setting. The fundamental behavioural assumption of cost minimization was re-examined by White (1988), who applied a form of linear programming commonly known as the transportation problem to estimate the minimized commute. In this approach, excess commuting was redefined as a deviation of the actual commute from the minimized commute obtained in the transportation problem. The majority of excess commuting research since White's work has made use of the transportation problem and has focused on the discussion concerning contextual, methodological and policy-related issues in relation to the non-optimized commute in the linear-programming approach.

Contextual issues have been concerned with the questions regarding the reason for the existence of substantial excess commuting and its socio-demographic determinants. Methodological issues have been concerned with the reasons why there have been widely divergent estimates. The jobs–housing balance, environmental and other social issues have also been discussed with respect to the policy implications. These are the main issues that have been addressed in the literature. The purpose of this paper is to review and summarize this research critically, and to understand why different conclusions have been reached, and to make suggestions on future research directions.

Two Different Approaches to Excess Commuting

Excess commuting is associated with the overall geographical disparity between jobs and housing because workers do not minimize their commuting travel for some reason. This examination of the spatial interaction between jobs and housing in terms of commuting behaviour has been extensively studied by urban transport planners, geographers and urban economists for more than 20 years. The discussion of excess commuting started from Hamilton's (1982) seminal study that investigated whether workers minimized their average commuting distance according to the optimization strategy of the monocentric model. The focus was on the non-optimized commuting measured by the difference between the actual average commute and the required commute predicted by the traditional monocentric model. This approach was applied to a number of US and Japanese cities, and the results demonstrated the huge amount of wasteful commuting that ranged from 70 to 87%. This result led him to question the validity of the monocentric model. Hamilton (1982, p. 1051) said, "these findings can hardly be taken as a ringing endorsement of the behavioural assumptions underlying the monocentric model".

A few years later, Hamilton's dramatic findings were re-examined by White (1988), who adopted a linear-programming approach[2] (a cost-minimizing assignment model) to calculate the minimized average commute.[3] Under this approach, a journey-to-work matrix (origin–destination matrix) is constructed to contain the elements n_{ij} showing the number of workers commuting from their residential place (zone i) to the work place (zone j). A corresponding matrix of commuting costs is also constructed to contain the elements c_{ij}. The linear programming reassigns the locations of jobs and residences to minimize the total average commuting costs to find the optimal journey-to-work flow (n^*_{ij}) in the origin–destination matrix:

$$\min \frac{1}{N} \sum_i \sum_j c_{ij} \cdot n_{ij}$$

subject to the constraints:

$$\sum_i n_{ij} = \sum_i n^*_{ij} = D_j \text{ and } \sum_j n_{ij} = \sum_j n^*_{ij} = O_i,$$

where D_j is the total employment in zone j, O_i is the number of workers living in zone i, and N is the total number of commuters. The amount of excess commuting (E) was then measured by:

$$E = \left(\frac{\bar{t} - \bar{\tau}}{\bar{t}}\right) * 100,$$

where $\bar{t}$ is the actual average commuting cost $(\bar{t} = \frac{1}{N}\sum_i \sum_j c_{ij} \cdot n_{ij})$ and $\bar{\tau}$ is the minimized average commuting cost $(\bar{\tau} = \frac{1}{N}\sum_i \sum_j c_{ij} \cdot n^*_{ij})$.

White (1988) demonstrated that there was a far smaller proportion of excess commuting (only 11% of actual commuting was excessive) as compared with Hamilton's, and argued that the predictive power of the monocentric models is better than that described by Hamilton. The considerable discrepancy between their findings was clearly explained by Small and Song (1992) who demonstrated that they had adopted different methodologies. Hamilton assumed that employment and population density function declines exponentially from the central business district (CBD), whereas White took the density pattern as it was. Thus, Hamilton had taken the modelling approach, whereas White had taken the empirical approach. Based on this argument, Small and Song concluded that a test of cost minimization needs to be separated from a test of cost minimization with monocentricity.

The follow-up study by Song (1995) showed that the transport problem could also be used to test three urban models: monocentric, polycentric and dispersed. He empirically tested which urban model better explain a worker's commuting behaviour. The analysis was carried out using the case study area covering five counties in the greater Los Angeles region, California, USA. Song found that the polycentric and dispersed density functions fit better than the monocentric function when explaining the actual distributions of jobs and residences. In the study, the amounts of excess commuting for the polycentric and dispersed models (59.11 and 53.10%, respectively) are significantly smaller than that for the monocentric models (81.59%), when the average minimum commutes implied by three models were compared with the actual commute. From the results, Song concluded that the behavioural assumption on workers' optimization strategy for their location decision should not be underestimated as this assumption is implicit in all the models he tested.

As described above, the earlier excess commuting literature was related to the discussion of the predictive power of monocentricity. Confusion resulted from different definitions of the minimum commute and this affected the interpretation of excess commute. Two different approaches—one using an urban economic model and the other cost minimization—serve different purposes, but both describe the important behavioural assumption on the cost optimization strategy in location choice. However, note that the optimization strategy in the monocentric model is different from that in the transportation problem. The transportation problem is concerned with a reallocation of workers that minimizes the total cost within the urban system, thus the optimized travel pattern may not characterize the individual decision-making strategy described in the monocentric urban model.[4] In addition, for the ideal world portrayed in the transportation problem, everyone needs to have perfect information about the decisions of other people and have a common purpose. Despite these strong assumptions, the majority of excess commuting research has used the absolute system minimization approach to describe the distribution of jobs and housing under the ideal conditions.

Since Hamilton (1982), there have been a well-established research thread looking at a variety of aspects of excess commuting (Table 1), and most contributions in this field have been made by studies using the transport optimization procedure. The discussions in the follow-up excess commuting literature from the 1990s can be divided into three major issues (Figure 1). The first is concerned with the question about why excess commuting exists and what factors are closely related to longer commuting (contextual issues). The second is focused on the inconsistency of excess commuting estimates (methodological issues). The third is concerned with the policy implications drawn from the discussion of excess commuting (policy-related issues). This paper now elaborates on and summarizes the discussion in the excess commuting literature under three main headings by

Table 1. Chronological list of selected literature that estimates excess commuting

Reference	Study area(s)	Cost unit used	Excess commuting (%)*	Main argument(s)
Hamilton (1982)	14 US cities 27 Japanese cities	distance time	87.1 70–77	Large amount of excess commuting represents the poor predictive power of the monocentric model
White (1988)	25 US cities	time	11.1	Predictive power of the monocentric model is not as bad as Hamilton (1982) predicted
Hamilton (1989)	Boston, MA	distance	47.1	Discrepancy between the White and Hamilton estimates was caused by within-zone commuting and the difference between time and distance
Cropper and Gordon (1991)	Baltimore, MD	distance	50–64	When other determinants of location choice are considered, excess commuting decreases
Thurston and Yezer (1991)	14 US cities	distance	32.7	Estimates of excess commuting are substantially reduced when heterogeneous households are taken into account in the monocentric model
Small and Song (1992)	Los Angeles, CA	distance time	69.1 65.9	White's LP approach is different from Hamilton's test of the monocentric model; aggregation bias is the major cause of the variation in estimates
Giuliano and Small (1993)	Los Angeles, CA	distance time	53.3–78.5 50.1–80.0	Commuting time and distance are not very sensitive to the jobs–housing balance
Kim (1995)	Los Angeles, CA	time	38.07	People have a tendency to minimize commutes subject to their constraints
Merriman *et al.* (1995)	Tokyo	time	15	Small excess commuting for the Tokyo area. The discrepancy between Small and Song and their estimates comes from the differences in methodologies, urban structure and institutions

Table 1. *(Continued)*

Reference	Study area(s)	Cost unit used	Excess commuting (%)*	Main argument(s)
Song (1995)	Los Angeles, CA	distance	53.1–81.6	Excess commuting decreases when a generalized urban form is considered
Scott *et al.* (1997)	Hamilton, Ont.	time	73.14	Excess commuting concept can be used to examine the change of potential emissions; geographical distribution cannot explain a large proportion of excess commuting
Frost *et al.* (1998)	ten UK cities at two points in time	distance	19.1–32.0	Decentralization of employees plays an important role in excess commuting estimates
Chen (2000)	Taipei	distance	79.9	Centralization of employment tends to lower the level of excess commuting; the jobs–housing balance has a small impact on the commuting pattern
Horner (2002)	26 US cities	distance	46.8–67.2	Concept of the theoretical maximum commute is useful for comparative urban analyses
Buliung and Kanaroglou (2002)	Toronto, Ont.	distance	65	Commute length could be reduced by the policy directed at particular commuter groups
Horner and Murray (2002)	Boise, ID	distance	26.2–48.1	Level of aggregation has a considerable impact on the excess commuting estimates
Manning (2003)	London	distance	55	Disaggregation analyses have little impact on the excess commuting estimates
Rodríguez (2004)	Bogotá	distance	47	Concept of voluntary and involuntary excess commuting could be incorporated into excess commuting calculations
O'Kelly and Lee (2005)	Boise, ID Wichita, KS	distance	47.7 55.7	Non-uniform excess commuting and jobs–workers ratios are found when disaggregate journey-to-work data for 14 different occupational groups are used
Ma and Banister (2006b)	Seoul at three points in time	distance time	51.3–59.5 30.2–28.4	Commuters in the Seoul metropolitan area have been trying to reduce both qualitative and quantitative imbalances based on time rather than distance

*Estimates from the subgroup analyses are not reported.
All studies primarily use the transportation problem, except for Hamilton (1982) and Thurston and Yezer (1991).

addressing the reasons for the differences between the estimations, whether they are contextual, methodological or policy-related.

Contextual Issues Concerning Excess Commuting

Throughout the previous excess commuting literature, findings of high excess commuting have been discussed with respect to several key factors. Such factors are considered to prevent urban workers from finding nearby jobs or residential locations, thus producing longer commute journeys and a higher level of excess commute. These factors have been seen as constraints that affect modern workers' location decision and many empirical trials have tried to relax the strong assumption that simplifies reality so that the possible causes of large amounts of excess commuting can be explained.

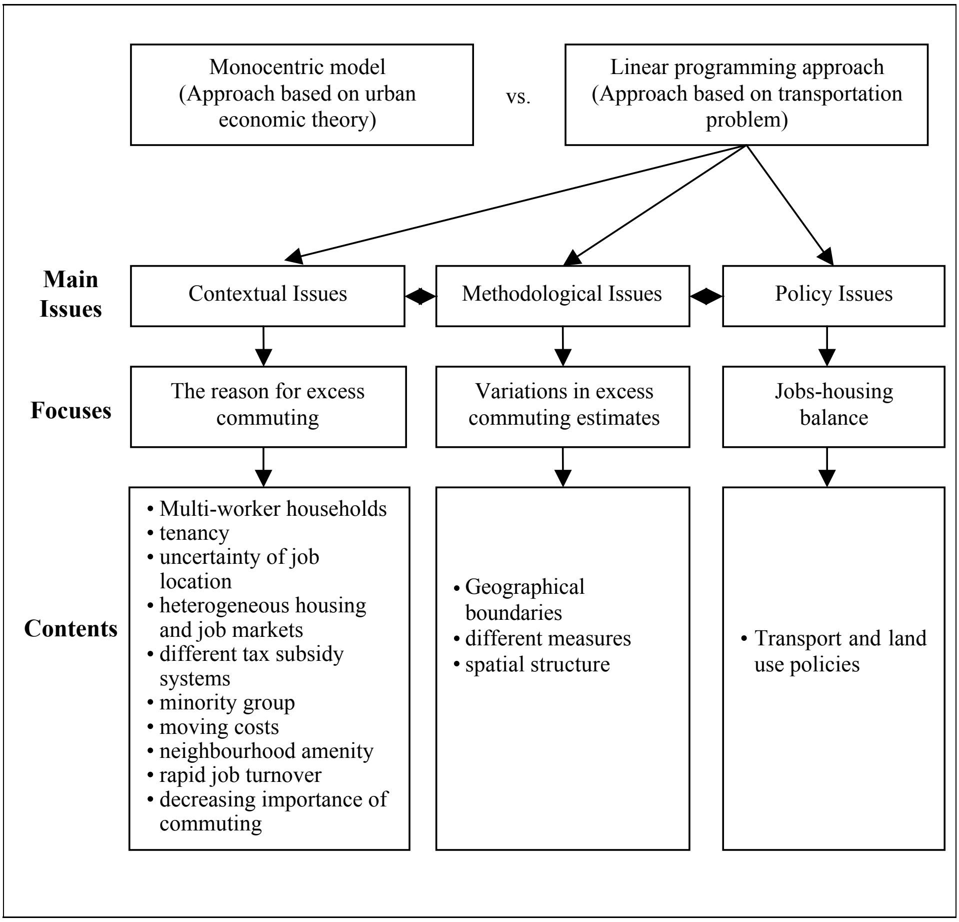

Figure 1. Three main issues in the excess commuting literature. This conceptual framework focuses on the linear-programming approach as the majority of excess commuting research since White (1988) made use of the transportation problem

The most frequently mentioned factors have been the increasing prevalence of two-worker households, as optimizing one worker's commute may increase that of the other. Two-worker households may have more constraints than single-worker households, but the linear transportation programming model treats these workers as if they live separately. An empirical study by Kim (1995) made an assumption that both workers in two-worker households need to move in tandem during the assignment process. Kim's results showed that controlling for the constraints on the mobility of two-worker households resulted in less excess commuting. This conclusion is supported by Buliung and Kanaroglou (2002), who demonstrated that the additional restriction of the mobility of multiple worker households significantly reduced the amount of excess commuting from 65 to 15% in the Greater Toronto area, Canada.

The tenancy status has also been considered as a key determinant causing larger excess commuting with respect to moving costs because homeowners tend to have greater moving costs that may restrict their mobility more than tenants (Crane, 1996). Cropper and Gordon (1991) estimated the parameters of the utility functions for both home-owners and renters in Baltimore, Maryland,[5] and found that the minimum commute is 5.04 miles for home-owners and 4.17 miles for renters. This result was supported by Kim (1995) who grouped the households by tenancy status and found that home-owners have higher excess commuting levels than renters.

The uncertainty of job location has been considered as one of the important determinants affecting the estimates of excess commuting. Crane (1996) argued that the past studies of excess commuting were so dependent on simplistic assumptions that they ignored the expectation of the future job locations that affects commutes. The analysis by Crane showed that those who have relatively unstable jobs are likely to have longer commutes because job uncertainty diminishes the value of access to the current jobs. Crane's findings are in line with those of Van Ommeren (1998, 2000) who demonstrated the strong correlation between the probability of being engaged in job search and commuting time, and who argued that the excess commuting could be associated with the expectation of job moving.

Some have suggested that job interchangeability is not common because of the heterogeneous housing and job markets (Hamilton, 1982; Giuliano and Small, 1993). This issue was empirically examined by Manning (2003) who disaggregated London data into a number of characteristics such as age and occupation, and checked whether there is a convergence towards actual commuting lengths when these restrictions are considered. Using the Greater London data from the 1991 Census, Manning analysed different age (seven categories) and occupation groups (23 categories). Surprisingly, he found only very small effects of disaggregation on the volume of excess commuting. In the male labour market, imposing an occupational constraint caused an increase in the minimum commute by an average of only 30 m. Also, age disaggregation caused a rise in the minimum commute by 40 m, which in practical terms means that there is a minimal effect on the amount of excess commuting. Manning's conjecture is that excess commuting is not likely to disappear by imposing more restrictions (or segmenting the labour market). He indicated that even among workers doing the same job, there is a large degree of pay variation, which is likely to lead to a certain amount of excess commuting. This finding conveys a stronger message about the importance of the heterogeneous housing and job market affecting excess commuting.

Possible reasons for large differences in excess commuting have also been attributed to the different subsidy systems for transport in different cities. Merriman *et al.* (1995) suggested that untaxed compensation of free parking in the USA may encourage workers to use cars. In contrast, workers in Japan who receive tax-free transit tickets may be encouraged to use public transit. The result is that in both cases workers become less concerned about the monetary cost of commuting, thus producing longer commuting journeys. The effects of the transport subsidies is more clearly encouraged by the fact that many workers in Europe are offered a company car within their compensation package, and 42% of all new automobiles are company cars (Van Ommeren *et al.*, 2002). Van Ommeren *et al.* concluded that transport subsidies have a positive effect on workers' journey-to-work time. Such incentives could make workers less sensitive to the monetary costs of commuting so that they modify their utility function and change home locations and travel behaviour.

The proportion of minority workers in the labour market (White, 1988) could explain some variations in excess commuting across global cities. It has been argued that in the USA the increasing decentralization of employment disadvantages minority groups who have less mobility and much of the spatial mismatch hypothesis literature provides either strong or moderate support for this hypothesis (Ihlanfeldt and Sjoquist, 1998). However, the racio-ethnic segmentation of US cities may not characterize other global cities, and this could cause the variation in excess commuting estimates. Using the case study of Seoul, South Korea, where racio-ethnic segmentation is not a pertinent issue, Ma and Banister (2006b) showed that the urban decentralization of jobs and housing could provide a potential for shorter commuting and all the four different occupational groups in Seoul could take advantage of the spatial processes of the urban decentralization to reduce their commuting times between 1991 and 2000.

Other factors that could influence the levels of excess commuting include the transaction costs of moving jobs or housing (Hamilton, 1982; Giuliano and Small, 1993; Levinson, 1998; Larsen *et al.*, 2004), neighbourhood amenity (Ma and Banister, 2006a), rapid job turnover (Giuliano and Small, 1993), imperfect labour market information (Rouwendal, 1998; Larsen *et al.*, 2004), and the increasing importance of non-work trips (Hamilton, 1982; Giuliano and Small, 1993). These factors have been mentioned as possible explanations of excess commuting, but very few of them have been incorporated into the excess commuting model itself. But it is often assumed that the inflexibility of the labour market, more black and minority workers in the urban labour force, a decrease in the mobility of workers, and the growing non-work trips are all likely to increase the amount of excess commute.

Despite the considerable efforts to identify the possible determinants of excess commuting, the necessity of reducing this unwanted travel could be questioned by the fact that the noticeable invariability of average travel times that is often found in many studies, regardless of the widely differing income levels, geography and transportation infrastructures (Schafer, 1998). Such a consistency of average travel times implies that there may be a commuting pattern that cannot be easily changed. Levinson and Kumar (1994) tested the hypothesis that the relocation of households and workplaces make commuting times stable as the decentralization of urban form progresses. Comparing the Metropolitan Washington Council of Government between 1968 and 1988, they identified that the average commuting time of the Washington metropolitan region was 32.5 min in both 1968 and 1988, indicating that both housing and firms seek to bring about a jobs–housing balance, even though travel distance becomes longer over time. Gordon *et al.*'s (1991) findings from American Housing Survey and census data indicate that average commuting times are contained by the location adjustments of jobs and housing. This is another example that illustrates the statement that "excess commuting might not be really excessive".

The observed regularity of commuting time has also been discussed with respect to the inevitable commuting, which is defined as the necessary minimal commuting thought to be unavoidable (sometimes desirable) in a community. The value of true excess commuting can be obtained after discounting other factors such an inevitable commuting. The notion of a psychological buffer between home and work activities (Giuliano and Small, 1993) and the human preference for roaming or expressing territoriality (Marchetti, 1994) could explain the existence of excess commuting, at least in part (Levinson, 1998). Mokhtarian and Salomon (2001) argued that people possess an intrinsic desire to travel, thus travel can have a positive utility. Their result from the surveys in the San Francisco Bay Area showed that the average ideal one-way commute time was 16 min. In the contextual sense, these 16 min should not be included in the amount of excess commuting, but such an ideal commuting time may not be generalized as it varies across the cities due to different culture, transport system, demographic composition, etc. The idea of a "maximum acceptable commuting distances" described by Getis (1969) may reflect these notions of ideal commutes (Rouwendal, 2004). Despite such intuitively appealing explanations, these approaches can only explain part of the excess commuting, thus failing to address a wide range of individual variation in travel behaviour.

From this discussion of some of the contextual issues and problems surrounding the concept of excess commuting, certain conclusions can be drawn. It is not surprising that excess commuting exists, as the real distribution of jobs and people within cities is never likely to be optimal, and even if it was it might only reflect the situation at one point in time. Also, the variation in excess commuting estimates between cities could occur due to different contextual factors such as the participation of female workers, labour market segmentation, transport policy, etc. The conventional approach tries to explain excess commuting solely in terms of the spatial structure of the city, but this has now been extended to include a wide range of social factors. The extended approaches also include heterogeneity assumptions on the nature of jobs and the social characteristics of the people, but other factors such as market inertia, the costs of moving, and amenity or neighbourhood quality may also affect location and levels of commuting. It means that jobs and housing could potentially be optimally distributed according to other criteria, while sub-optimal from a commute minimization perspective. In addition to physical and social factors, there may be psychological dimensions, as people may want to separate homes from workplaces, and they 'value' the time taken to switch from one to the other.

Methodological Issues Concerning Excess Commuting

Previous studies have produced quite divergent estimates of excess commuting even when similar approaches are applied to the same case study area (Small and Song, 1992; Giuliano and Small, 1993). There have been a number of trials verifying the linear-programming approach. Their intention has been to make the linear-programming technique more reliable, and this has provided valuable lessons on the technical subtleties of the ways in which excess commuting changes. Three major methodological issues have been addressed with respect to the linear-programming technique: geographical boundaries, travel cost measures and spatial structure.

Effects of the Geographical Boundaries on the Excess Commutes

The linear transportation programming model needs the origin and destination matrix, which is usually based on Traffic Analysis Zones (TAZs). The variation in these areal units (e.g. the size of zones and the number of zones) used in different metropolitan areas may have an impact on the estimation of excess commuting. The zonal issue was mentioned by White (1988, p. 1108) when she first adopted a linear transport programming model for the estimation of excess commuting. The lower level of aggregation of zones tends to diminish the proportion of excess commuting because the transportation optimization model does not change jobs or residential places to minimize work trips within a zone. In the most extreme case, excess commuting is zero when the number of zones is one.

Small and Song (1992) further investigated this problem and argued that this aggregation bias is more serious than expected. In their study there was a huge difference of the estimated excess commuting between aggregated and disaggregated data. They found that if large zones are used, about one-third of the actual commuting turned out to be excessive. In contrast, if small zones are used, about two-thirds of commuting is classified as excessive commuting, indicating that the amount of excess commuting is very sensitive to the level of aggregation. Merriman *et al.* (1995), however, showed contradictory results about the impact of the aggregation into a smaller number of zones using data for the Tokyo metropolitan area. They demonstrated that aggregating zones has a very modest impact on the estimation of excess commuting. Their results demonstrated that excess commuting was 15% when disaggregated zones (n = 211) were used, whereas the most aggregated zones (n = 16) produced the average excess commuting of 12%.

This variance in excess commuting estimate is closely related to the Modifiable Areal Unit Problem (MAUP), which has been viewed as endemic to the spatial analysis that utilizes aggregate data sources (Openshaw and Taylor, 1981). The MAUP always arises when the boundaries in the study area are arbitrarily modifiable and defined. The effects of MAUP consist of both scale and zoning effects: the scale effect relates to the variation that occurs when the same set of areal units is grouped into larger ones; and the zoning effect is the variability in results that can occur when the set of areal units is recombined into zones in a different way (Armhein, 1995) (Figure 2). The importance of this issue is well reflected by Openshaw and Taylor (1979) who demonstrated that the correlation between the percentage of Republican voters and the percentage of elderly voters in Iowa counties can vary between –0.811 and +0.979 by manipulating the scale and zoning strategies.

The latest study by Horner and Murray (2002) carefully examined the impact of aggregation and spatial unit definition on the results of excess commuting. Their study was applied to Boise, Idaho, and the data were initially divided into 286 TAZs. They used the Thiessen aggregation approach to change the aggregation level from 275 to 25 in increments of 25 zones. The analysis was carried out for the 100 different zoning configurations (different unit specifications) for each zonal

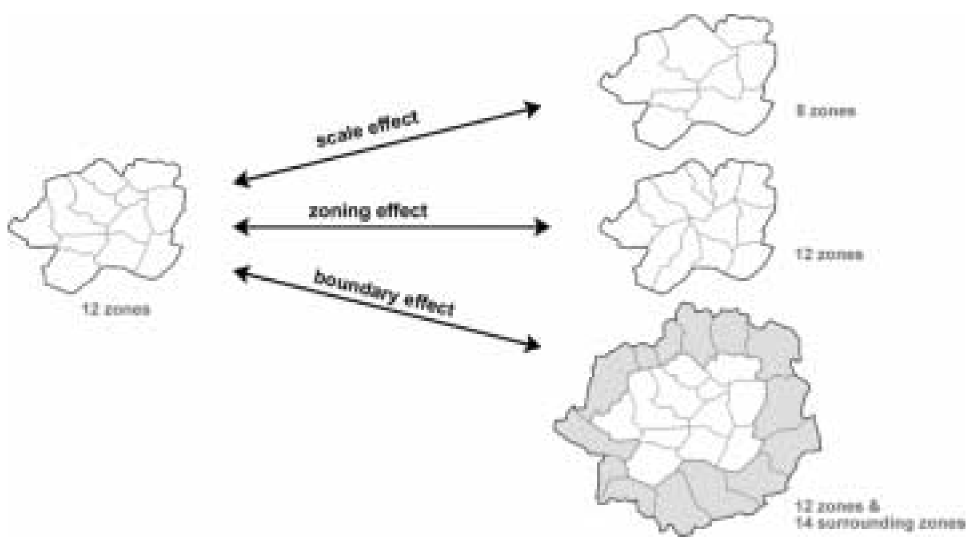

Figure 2. Examples of possible biases caused by arbitrary geographical boundaries

aggregation level, *n*. Horner and Murray found that the average estimate of excess commuting was 48.07% when highly disaggregated zones (n = 275) were used, whereas the most aggregated zones (n = 25) produced the average excess commuting of 26.21% (range 11.6–37.13% excess commuting). The results showed that excess commuting tends to decrease as the level of aggregation increases by reducing the gap between the actual and minimum commute. This finding again reconfirms the uncertainty in the estimation of the excess commuting measure suggested by Small and Song (1992). Based on the findings, they concluded that the more aggregated is the zone, the more likely is the zonal aggregation bias problem, thus data sources should be as disaggregate as possible. They also suggested that the only way to avoid the areal unit problems is to use individual-level micro-data as in Cropper and Gordon (1991) and Kim (1995) as the use of such data is not affected by the areal units.

City (or regional) boundary issue can also be related to the geographical scale issue. Frost *et al.* (1998) were the first to identify the impact of the position of boundaries drawn around a city on the estimation of excess commuting using ten British cities in 1981 and 1991. They extended this method by including the journey-to-work trips (inward commute) made by those with jobs in the city but who live outside the city. The major finding of this study is that the amount of excess commute is much smaller when such an inward commuting is incorporated into the transportation optimization model, and the decentralization of employment in the case study cities had decreased the amount of excess commuting between 1981 and 1991.

The issue on the position of boundaries is closely related to that of spatial structure issues and provides further insights into the impact of urban structure on the estimation of excess commuting. When the area surrounding a large city is mainly used for residential purposes (e.g. when the city structure is similar to monocentricity and where there is the absence of affordable or suitable jobs near housing), extending the boundary of the study area is likely to produce smaller levels of excess commuting by increasing the minimum commute faster than the actual commute. Frost *et al.* (1998) provided a good example in that their analysis was based on the assumption that the external zone where inward commuters originate from does not contain workplaces. From the discussion it can be concluded that in a relatively monocentric city structure, the amount of excess commuting is likely to decrease as the size of the study area boundaries increases (Figure 2).[6] Therefore, it is concluded that the position of boundaries could have an influence on the amounts of excess commuting.

Effects of Different Measures on Excess Commutes

The most frequently used travel cost measures in the estimation of excess commuting are distance and time. Travel distance could also be divided into straight-line and network distance. Network-based travel distance is a better measure than straight-line distance in that the former may reflect the real road situation affecting workers' travel behaviour. On the other hand, the travel time could be divided into door-to-door commuting and over-the-road commuting times. The latter differs in that it does not consider the 'fixed-time costs' such as parking and getting to and from where the car is parked (Merriman *et al.*, 1995). With regard to travel times, a further distinction can be drawn whether travel times are emerged under free-flow or congested traffic conditions. Scott *et al.*

(1997) used travel times that take into account modal split and traffic condition on the road network.[7]

In the earlier literature, White (1988) convincingly asserted that commuting time is a better measure than commuting distance because workers consider travel time much more than travel distance as a cost. The important implication to note is that the use of different measures may produce different outcomes of excess commuting if time is not proportional to distance. Hamilton (1989) estimated the quadratic equation:

$$T = \alpha_0 + \alpha_1 D + \alpha_2 D^2,$$

where T is 'time' and D is 'distance', using Boston census data. This quadratic equation assumed that commuting time has a positive relationship to distance, but at a certain point the former decreases as the latter increases (in the equation, it is assumed that α_0 and α_1 are positive and α_2 is negative). Hamilton explained that the intercept, α_0, can be interpreted as fixed-time costs and suggested that if there is a large fixed-time cost that cannot be minimized in the transportation assignment, this may be attributable to the smaller excess commuting when time is used. In addition, the bigger $|\alpha_2|$ indicates that fact that longer commutes are more likely to be related to higher speed. The equation Hamilton applied to Boston using census data proved α_0 (16.969 min) is very large when compared with an average actual commute of about 22 min. The research by Small and Song (1992) and Giuliano and Small (1993) showed empirically contrasting views about Hamilton's interpretations. Their estimation:

$$T = 7.31 + 1.64D - 0.00255D^2, \qquad R^2 = 0.97$$

demonstrated a more proportional relationship between time and distance than they do in Hamilton's:

$$T = 16.97 + 1.54D - 0.0166D^2, \qquad R^2 = 0.43.$$

The smaller α_0 and $|\alpha_2|$ result in the difference between the distance- and time-based estimates in Los Angeles being reduced.

This interesting argument was re-examined by Ma (2004) who showed that the results from Seoul do support Hamilton's conjecture about the non-proportional relationship between time and distance. Ma tested three possible models: (1) linear: $T = b_0 + b_1 D$; (2) quadratic: $T = b_0 + b_1 D + b_2 D^2$; and (3) power: $T = b_0(D^{b_1})$ (or, $\ln(T) = \ln(b_0) + b_1 \ln(D)$), where T is time, b_0 is a constant, b_n is a regression coefficient, and D is distance. Results for Seoul suggest that the best-fit equation is the power model:

$$T = 24.3D^{0.35}, \qquad R^2 = 0.547 \text{ in } 1990$$
$$T = 19.5D^{0.38}, \qquad R^2 = 0.613 \text{ in } 1995$$
$$T = 24.3D^{0.38}, \qquad R^2 = 0.592 \text{ in } 2000$$

indicating that commuting time is not proportional to distance (Figure 3),[8] thus producing lower excess commuting. Ma (2004) and Ma and Banister (2006b) have demonstrated the significant difference between the distance- and time-based estimates (Table 1) as commuters have been more concerned with travel time

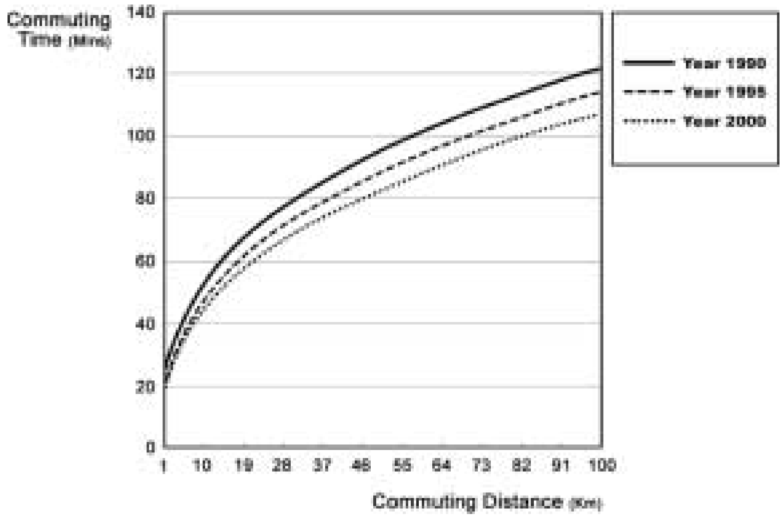

Figure 3. Relationship between time and distance based on Power model estimation using data from Seoul, South Korea. *Source:* Ma (2004)

rather than travel distance, and they concluded that the discrepancy may be the major cause of the variance in excess commuting estimates.[9]

More generally, the argument here is that there is a strong intuitive reasoning for travel times to be used wherever possible, particularly if they cover door-to-door times. The reasoning here is that as travel times embody factors such as the travel speed, mode and traffic situations, commuters see time as the main constraint to where they work. Distance can be overcome by using faster modes, and this has been evident in all studies that use data collected at multiple points in time. Over time, the physical Euclidean distance has been constant, but the relative time distance has changed and affected workers' location decision. The concept of time–space convergence conveys such an idea that a decrease in the friction of distance between places has been caused by the use of faster and more efficient travel modes (Janelle, 1969). This also helps explain the spread of cities over time.

Effects of Spatial Structure

Even though most excess commuting literature has been concerned with spatial distribution patterns, only a few researchers have mentioned the possible impact of urban spatial structure on the estimates of excess commuting. The empirical evidence by Frost *et al.* (1998) showed that the changes associated with the decentralization of employees are related to a decrease in excess commuting as the average minimum commute increases faster than average actual commute. The arguments from Chen (2000) are in line with the findings from Frost *et al.*:

> The greater the centralization of employment, or the more inter-city inward commuters, then the lower the gap will be between the required commute and the actual commute, with a resultant lower level of excess commutes.
>
> (Chen, 2000, p. 171)

Ma and Banister (2006a) indicated that according to the traditional excess commuting measures (both White's and Hamilton's methods), the amount of excess commuting is zero under complete employment centralization, regardless of how long is the commuting length. In the monocentric city, the minimum commute is the same as the actual commute because it is impossible to trade jobs and residential places in the transportation assignment process.[10] This implies that, in reality, an extremely high concentration in a central city is likely to have smaller amounts of excess commute than the dispersed or polycentric city. The interpretation of excess commuting becomes more difficult and complicated when the dynamic nature of urban form is considered. For example, the transformation to a polycentric city may shorten journey-to-work trip length by locating people and firms closer together, but this may produce a larger estimate of excess commuting. The implication is that the excess commuting measure as a means of addressing the urban efficiency issue could produce a misleading conclusion when urban structure is not taken into account. The importance of this spatial consideration is more pronounced when different cities are compared and when different time points are used in a comparative analysis.

All three of these methodological issues have been addressed in the literature, and all studies should be aware of the potential pitfalls in the estimation of excess commuting. It may also limit the usefulness of the method, particularly if comparisons are made between the results at different times from different cities, where different assumptions have been used. When time-based analysis in the same city is used, then it is important to ensure that there is internal consistency in the data, including the aggregation methods used, the boundaries of the zones and the city itself, and the measure of commuting used (time or distance).

Policy Issues Concerning Excess Commuting

Excess commuting has been considered as a strategic useful tool for addressing transport and planning policies with respect to the jobs–housing balance, environmental and other social issues. In the previous literature, the policy implications have mainly been discussed in terms of the redistribution of workers and the land-use mix policy. It has also been mentioned in other literature, such as that explaining the determinants of longer commute, urban compactness, decentralization/poly-centralization, road pricing, housing policy, and zoning regulations.

The amount of excess commuting implies substantial potential savings in commuting that could be derived by inducing workers to change their locations. The excess commuting captures a fascinating idea in which such savings could be feasible even without restructuring the physical plans of the cities. The jobs–housing ratio, which is the most frequently used jobs–housing balance measure, is often compared with the theoretical minimum commute in the linear-programming approach as a measurement of the proximity of jobs and housing. One interesting feature of this technique is that it can measure both the actual average commute and the proximity measure of jobs and housing at the same time. The comparison between the actual average and the theoretical minimum commutes (e.g. Giuliano and Small, 1993; Horner, 2002) enables an additional appreciation of the efficacy of the mixed land-use policy.

A jobs–housing balance policy has been viewed as one of the ways to alleviate traffic congestion and emissions. The impact of urban travel efficiency on congestion and automobile emissions was discussed by Scott *et al.* (1997), who used the concept of excess commuting as a benchmark to examine potential reduction in automobile emissions. A base commuting and an optimum commuting scenarios were generated for the Hamilton Census Metropolitan Area through an integrated land-use and transportation simulation model, and the estimated emissions of hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxides (NO_x) were compared for two commuting scenarios. Scott *et al.* (1997) showed that change from the base to optimum scenario reduces aggregate emissions of HC, CO and NO_x by 66, 62 and 56%, respectively. Their analysis implies that encouraging more efficient commuting could significantly reduce the amount of automobile emissions.

The excess commuting analysis also tried to provide other policy directions and advice through disaggregate analysis. Cropper and Gordon (1991), Kim (1995), Buliung and Kanaroglou (2002), Horner (2002), Manning (2003), O'Kelly and Lee (2005) and Ma and Banister (2006b) have all demonstrated that particular socio-economic groups could have longer commuting trips than others, depending on whether the constraints on the mobility of the group is imposed, or whether the data are broken down by different socio-demographic characteristics such as occupation and sex. The results show that the proportion of excess commuting tends to vary considerably according to the labour market segmentations that share similar characteristics such as locational patterns and travel behaviours. This implies that a policy targeted at reducing the length of the commute for a particular group could disadvantage other workers who are not targeted. It provides a better understanding of why the policy relating transport and land-use mix needs to consider the difference resulting from labour market segmentation.

In relation to the segmentation of the labour market, there is also strong evidence that minority groups such as low-income households have less accessibility to jobs (Kain, 1968; Raphael, 1988) due to the housing market segregation caused by suburban housing discrimination and exclusionary zoning practices. Some people whose mobility constraints are greater than others could have a longer commute than the overall average. The means by which the accessibility of low-income households to the jobs could be increased has not been discussed in the excess commuting literature, but Martin (2001) demonstrated that policies aimed at giving opportunities for low-income households to move nearby jobs might be more effective than providing commuting cost subsidies.

However, it is interesting to note that the results from the excess commuting literature have rarely been used to support real-world policy even though it has been under study for more than 20 years. Part of the reasons for this could be blamed on uncertainties surrounding excess commuting measure. Such uncertainties are related to contextual issues as well as to technical issues mentioned in the previous section. Much of the excess commuting literature acknowledges that the individual choice of job or house can deviate from the optimized scenario for perfectly rational reasons. It is hard to prove to what extent there is a 'real' excess commuting that one could aim to reduce. Without a proper understanding of this, any attempt to reduce workers' commuting time via policy advocating jobs–housing balance may have disappointing results (Giuliano and Small, 1993; Scott *et al.*, 1997). The ongoing debate on the merits and implications of the jobs–housing balance shows that this issue is still far from resolved (Horner, 2004). Despite this, it is generally assumed that the jobs and housing balance is a necessary condition, even though it is not sufficient to guarantee efficient commuting patterns.

The declining importance of journey-to-work trips makes it more difficult to focus on policy for reducing journey-to-work trips. The recent growth of trips for other purposes may also result in longer commuting because many households may consider trade-offs among a number of possible activities (e.g. families with children may prioritize access to good schools) (Richardson and Gordon, 2001). This means that a policy of jobs–housing balance could cause a greater daily travels if the spatial distribution of non-work trips is not jointly considered. Therefore, minimizing the commute should not be a policy target on its own (Ma and Banister, 2006a), particularly when non-work trips are increasingly important in the policies aimed at enhancing local and regional accessibilities (Handy, 1993).

The increasing uptake of teleworking could also be taken into account with in the discussion of policy for jobs–housing balance. Teleworking is an emerging work pattern that could potentially reduce or eliminate physical commuting. A significant number of employees teleworks in the developed countries, and this new working pattern is expected to grow in the future (Jones, 2005). The possible impact of teleworking is that it could be replaced by other travel and/or it could cause a possible reduction in travel frequency, but facilitate longer distance travel (Banister 2005). The policy focused only on minimizing commuting distance may not be justified on the ground that it will promote more sustainable travel patterns.

Conclusions

Excess commuting has been an intriguing construct in both understanding and evaluating the urban commuting efficiency. Many studies of excess commuting have been focused on a variety of factors affecting the quantity of excess commuting partly in the hope of finding an effective solution for reducing this 'more-than-necessary travel'. These studies have made valuable contributions to the literature by providing a better understanding of longer commuting journeys. Longer commuting journeys have important policy implications, particularly when set within the sustainable development debate. Living further away from their jobs means that the association between jobs and housing becomes weaker as people accept longer commuting distances for other reasons. Experience from industrialized countries indicates that commuting distances have increased in the past several decades, but travel times have shown no clear pattern (for daily mobility for seven Organization for Economic Co-operation and Development (OECD) countries, see Schafer, 2000), implying that faster modes are being used. This trend towards urban decentralization is consistent across a variety of cities with different urban forms.

This paper has tried to provide a brief but reasonably detailed review of a number of key considerations relating to the difficulties of measuring excess commuting and in the interpretation of the output. Even though much useful work has been done in the past on studies that have provided a better understanding of the existence of excess commuting, there is still a substantial part that remains unexplained. The contextual issues have been concerned with the questions of why the observed average commute in the urban area has deviated from a theoretical minimum commute and what factors can explain such a deviation. The technical reliability issues also lie at the heart of the excess commuting debate, and this makes the general judgement on the nature and scale of excess commuting tentative. The complexity of travel behaviour combined with the bias issues embedded in the transportation problem requires more careful interpretations, especially in a comparative study between different cities and at different time points.

It seems that any contextual and policy-related interpretations of excess commuting are inevitably dependent on the reliable estimation methods. This is because the meaningful interpretation of behavioural phenomena should be based on the method for objective observation and estimation. Therefore, the most obvious future direction in research should involve further discussion of the methodological issues. The quantitative measurement of urban travel efficiency that could universally be used in a comparative study is a priority and this topic needs to attract more attention from researchers as it can show the relative performance of each city in terms of sustainable developments and provide direct policy-guidance for evaluating jobs and housing imbalance. The future research needs to provide more clarity on the issues raised and described herein.

Notes

1. Hamilton used both population and employment density gradients that Macauley (1982) updated from Mills's (1972) results to estimate the negative exponential density gradients. In his study, the mean optimum commute was defined as the difference between "mean distance of households from the CBD" and "mean distance of jobs from the CBD". This mean optimum commute was compared with the mean actual commute to calculate the amount of excess commuting.
2. Hitchcock (1941) was the first to develop this optimization model, which is known as the transportation problem.
3. In terms of evaluating a theoretical minimum commute, the first example of the application of the linear-programming approach can be seen in Hamburg *et al.* (1965). They introduce a measure called an "index of indifference", which assesses the extent to which commuters are indifferent to travel time. In their study, indifference to travel time was reflected by the 'probable' distribution in which the friction of space measured in time units were zero. This index is calculated by the proportion of the difference between actual and minimum commutes compared with the difference between the probable and minimum commutes. Note that both excess commuting and indifference index measures focused on how far actual commute deviates from the minimized commute.
4. The monocentric model is based on a theory of individual household location choice, which is an extension of consumer-behaviour theory. The residential bid-rent function is obtained by assuming that each individual household tries to maximize their satisfaction with respect to the consumption of housing and commuting.
5. They calculated excess commuting using household utility constraints that no household's utility is lowered during the assignment process.
6. Their case is related to boundary expansion. However, the size of the study area boundaries could decrease, in which case the amount of excess commuting is likely to increase.
7. They argued that previous studies that do not consider changes in inter-zonal travel times when journey-to-work matrices are optimized can underestimate excess commuting. This is because inter-zonal travel times can be reduced due to reductions in congestion that can be facilitated by shorter trips and changes in modal split.
8. The results also indicated that both linear and quadratic models seem to have rather unreliable intercepts due to too large fixed-time costs that do not seem to be intuitively plausible.
9. When the excess commuting is investigated in relation to possible environmental effect, the distance measure may be better as energy consumption is more likely to be associated with trip distance. Travel time has a subsidiary importance as it is related to the speed that affects fuel consumption (Banister, 2005).
10. In a complete monocentric structure, the only way to reduce the actual average commute is to move workers closer to the urban centre. However, note that when using micro-data and door-to-door travel cots, minimum commutes will never be zero unless individuals work from home.

References

Alonso, W. (1964) *Location and Land Use* (Cambridge, MA: Harvard University Press).

Armhein, C. (1995) Searching for the elusive aggregation effect: evidence form statistical simulations, *Environment and Planning A,* 27, pp. 105–120.

Banister, D. (2005) *Unsustainable Transport: City Transport in the New Century* (London: Routledge).
Buliung, R. N. and Kanaroglou, P. S. (2002) Commute minimization in the Greater Toronto Area: applying a modified excess commute, *Journal of Transport Geography,* 10, pp. 177–186.
Chen, H. P. (2000) Commuting and land use patterns, *Geographical and Environmental Modelling,* 4, pp. 163–173.
Crane, R. (1996) The influence of uncertain job location on urban form and the journey to work, *Journal of Urban Economics,* 39, pp. 342–356.
Cropper, M. and Gordon, P. (1991) Wasteful commuting: a re-examination, *Journal of Urban Economics,* 29, pp. 2–13.
Frost, M., Linneker, B. and Spence, N. (1998) Excess or wasteful commuting in a selection of British cities, *Transportation Research A,* 32, pp. 529–538.
Getis, A. (1969) Residential location and the journey from work, *Proceedings of the Association of American Geographers,* 20, pp. 55–59.
Giuliano, G. and Small, A. K. (1993) Is the journey to work explained by urban structure?, *Urban Studies,* 30, pp. 1485–1500.
Gordon, P., Richardson, H. W. and Jun, M. J. (1991) The commuting paradox: evidence from the top twenty, *Journal of the American Planning Association,* 57, pp. 416–420.
Hamburg, J., Guinn, C., Lathrop, G. and Hemmens, G. C. (1965) Linear programming test of journey to work minimization, *Highway Research Record,* 102, pp. 67–75.
Hamilton, B. W. (1982) Wasteful commuting, *Journal of Political Economy,* 90, pp. 1035–1053.
Hamilton, B. W. (1989) Wasteful commuting again, *Journal of Political Economy,* 97, pp. 1497–1504.
Handy, S. (1993) Regional versus local accessibility: implications for nonwork travel, *Transport Research Record,* 1400, pp. 58–66.
Hitchcock, F. L. (1941) The distribution of a product from several sources to numerous localities, *Journal of Mathematical Physics,* 20, pp. 224–230.
Horner, M. W. (2002) Extensions to the concept of excess commuting, *Environment and Planning A,* 34, pp. 543–566.
Horner, M. W. (2004) Spatial dimensions of urban commuting: a review of major issues and their implications for future geographic research, *Professional Geographer,* 56, pp. 160–173.
Horner, M. W. and Murray, A. T. (2002) Excess commuting and the modifiable areal unit problem, *Urban Studies,* 39, pp. 131–139.
Ihlanfeldt, K. R. and Sjoquist, D. L. (1998) The spatial mismatch hypothesis: a review of recent studies and their implications for welfare reform, *Housing Policy Debate,* 9, pp. 849–892.
Janelle, D. G. (1969) A spatial regorganization: a model and concept, *Annals of the Association of American Geographers,* 59, pp. 348–364.
Jones, C. (2005) *Teleworking: The Quiet Revolution* (Stamford: Gartner). Available at: http://www.gartner.com
Kain, J. F. (1968) Housing segregation, negro employment, and metropolitan decentralisation, *Quarterly Journal of Economics,* 82, pp. 175–179.
Kim, S. (1995) Excess commuting for two-worker households in the Los Angeles metropolitan areas, *Journal of Urban Economics,* 38, pp. 166–182.
Larsen, M. M., Pilegaard, N. and Van Ommeren, J. N. (2004) *Congestion and Residential Moving Behaviour.* Discussion Paper No. TI 2004-096/3 (Amsterdam: Tinbergen Institute).
Levinson, D. M. (1998) Accessibility and the journey to work, *Journal of Transport Geography,* 6, pp. 11–21.
Levinson, D. M. and Kumar, A. (1994) The rational locator, *Journal of the American Planning Association,* 60, pp. 319–332.
Ma, K. (2004) The impact of urban spatial decentralisation on jobs–housing imbalance. Unpublished PhD thesis, The Bartlett School of Planning, University College London.
Ma, K. and Banister, D. (2006a) Urban spatial change and excess commuting, *Environment and Planning A* (forthcoming).
Ma, K. and Banister, D. (2006b) Extended excess commuting: a measure of jobs–housing balance, *Urban Studies* (forthcoming).
Macauley, M. (1982) 1970 and 1972 estimates of Mills density gradients, unpublished manuscript, Johns Hopkins University.
Manning, A. (2003) The real thin theory: monopsony in modern labour markets, *Labour Economics,* 10, pp. 105–131.
Marchetti, C. (1994) Anthropological invariants in travel behaviour, *Technological Forecasting and Social Change,* 47, pp. 75–88.

Martin, R. W. (2001) Spatial mismatch and costly suburban commutes: can commuting subsidies help?, *Urban Studies,* 38, pp. 1305–1318.

Merriman, D., Ohkawara, T. and Suzuki, T. (1995) Excess commuting in the Tokyo metropolitan area: measurement and policy simulations, *Urban Studies,* 32, pp. 69–85.

Mills, E. S. (1972) *Studies in the Structure of the Urban Economy* (Baltimore, MD: Johns Hopkins).

Mokhtarian, P. L. and Salomon, I. (2001) How derived is the demand for travel? Some conceptual and measurement considerations, *Transportation Research A,* 35, pp. 695–719.

Muth, R. F. (1969) *Cities and Housing: The Spatial Pattern of Urban Residential Land Use* (Chicago, IL: University of Chicago Press).

O'Kelly, M. E. and Lee, W. (2005) Disaggregate journey-to-work data: implications for excess commuting and jobs–housing balance, *Environment and Planning A,* 37, pp. 2233–2252.

Openshaw, S. and Taylor, P. J. (1979) A million or so correlation coefficients, in: N. Wrigley (ed.) *Statistical Methods in the Spatial Sciences,* pp. 127–144 (London: Pion).

Openshaw, S. and Taylor, P. J. (1981) The modifiable areal unit problem, in: N. Wrigley and R. J. Bennett (eds) *Quantitative Geography,* pp. 60–69 (London: Routledge & Kegan Paul).

Raphael, S. (1998) The spatial mismatch hypothesis and black youth joblessness: evidence form the San Francisco Bay Area, *Journal of Urban Economics,* 43, pp. 79–111.

Richardson, H. W. and Gordon, P. (2001) Compactness or sprawl: America's future vs. the present, in: M. Echenique and A. Saints (eds) *Cities for the New Millennium,* pp. 53–64 (London: Spon).

Rodríguez, D. A. (2004) Spatial choices and excess commuting: a case study of bank tellers in Bogotá, Colombia, *Journal of Transport Geography,* 12, pp. 49–61.

Rouwendal, J. (1998) Search theory, spatial labor markets, and commuting, *Journal of Urban Economics,* 43, pp. 1–22.

Rouwendal, J. (2004) Search theory and commuting behaviour, *Growth and Change,* 35, pp. 391–418.

Schafer, A. (1998) The global demand for motorized mobility, *Transportation Research A,* 32, pp. 455–477.

Schafer, A. (2000) Regularities in travel demand: an international perspective, *Journal of Transportation Statistics,* 3, pp. 1–31.

Scott, D., Kanaroglou, P. and Anderson, W. (1997) Impact of commuting efficiency on congestion and emissions: case of the Hamilton CMA, Canada, *Transportation Research D,* 2, pp. 245–257.

Small, A. K. and Song, S. (1992) Wasteful commuting: a resolution, *Journal of Political Economy,* 100, pp. 888–898.

Song, S. (1995) Does generalizing density functions better explain urban commuting?, some evidence form the Los Angeles region, *Applied Economic Letters,* 2, pp. 148–150.

Thurston, L. and Yezer, A. M. J. (1991) Testing the monocentric urban model: evidence based on wasteful commuting, *AREUA Journal*, 19, pp. 41–51.

Van Ommeren, J. N. (1998) On-the-job search behaviour: the importance of commuting time, *Land Economics,* 74, pp. 526–548.

Van Ommeren, J. N. (2000) *Commuting and Relocation of Jobs and Residences* (Aldershot: Ashgate).

Van Ommeren, J. N., Van der Vlist, A. and Nijkamp, P. (2002) *Transport-related Fringe Benefits.* Discussion Paper No. TI 2002-063 (Amsterdam: Tinbergen Institute).

White, M. J. (1988) Urban commuting journeys are not 'wasteful', *Journal of Political Economy,* 96, pp. 1097–1110.