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Commuting and Land Use Patterns

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ABSTRACT *The assumption in cost minimization behavior is that a close relationship exists between urban structures and commuting patterns. Thus, an investigation of cost minimization could be undertaken by examining the existing relationship between land use and commuting patterns. Such an examination is undertaken by investigating the relationship between urban structures and commuting, using the following two measures: excess commuting and jobs/housing balance. Given the actual land use pattern in 1990, the requisite commuting distance in the Taipei metropolitan region is estimated. The results demonstrate a 79% excess commuting rate, but also indicate that only a minor influence exists on commuting from the job/housing balance in the Taipei metropolitan region, a finding which calls into question cost minimization behavioral assumptions. When comparing these findings to studies undertaken in Los Angeles and Tokyo, within these two regions, the findings indicated differing degrees of excess commuting; the relatively low level of excess commuting found in Tokyo may be attributable to the relatively larger area of the unit zone. This study suggests that when undertaking any examination of excess commuting, both the utility constraint and the non-uniform land price distribution, are crucial areas for consideration, and for further research.*

Introduction

The standard model in urban economics (Fujita, 1989; Mills, 1972) suggests that, given the job location, households determine their residential locations based primarily upon a trade-off between the costs of commuting and land costs, a proposition known as the location equilibrium condition; all households achieve the same utility level in location equilibrium. Given the workplace location, the household's residential choice then determines the commuting and housing costs.

In the standard urban economics model, the suggestion is that the trade-off between housing and commuting costs essentially determines household residential location choices. This implies that, given the land use pattern, households choose their place of residence in order to maximize their utility, and that household equilibrium distribution is responsible for generating corresponding commuting flows. The suggestion is, therefore, that the relationship between work commuting patterns and a household's residential choice, is strongly influenced by the pattern of land use. Much of the policy analysis, and many of the economic models, are based on this belief, nevertheless the empirical evidence for such a belief is weak.

An important study was presented by Hamilton (1982), in which he claimed that

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observed commuting behavior did not match the predictions of the mono-centric urban model. He found that the average commute was actually much larger than the theoretical optimal commute, a result that questions the standard theory of land use. His findings gave rise to extensive discussion and response. White (1988) used a different approach to demonstrate results in contrast to Hamilton's findings, which subsequently led to Small and Song's (1992) attempts at resolving the debate. Giuliano and Small (1993) examined the relationship between commuting and urban spatial structure (land use pattern) using disaggregated data. They concluded that both time and commuting distance were not particularly sensitive to variations in the urban structure, and that assumptions in the standard model of cost minimizing behavior did not adequately explain commuting patterns. Many more studies have raised similar arguments, and increasing criticism, of the assumptions and implications of the standard model. More details of these works and the debate contained within them are presented in the next section.

This area of research has been investigated and discussed extensively, with studies being based on different methodologies, in different regions, and with various structures, and the wide divergence of the empirical results has raised considerable debate. The importance of the ongoing debate in this particular area of research is that it strongly questions textbook explanations on location theory, including the fundamental urban structure model, and its implied location behavior. Legitimate methodologies, along with universal empirical results and reasoning, are the major issues that related research is now striving to achieve.

The purpose of this paper is to investigate the suggestion that the behavior assumption in 'cost minimization' is inadequate, and to undertake an empirical re-examination of the relationship between commuting and urban spatial structure. We use disaggregated data on the greater Taipei metropolitan area to undertake this empirical examination.

Prior Research

Studies examining the effect that urban structure has upon commuting can be grouped into two distinct approaches: the excess commuting approach and the job/housing balance approach.

The Excess Commuting Approach

The research on excess commuting attempts to investigate the adequacy of the assumption that commuting cost minimization behavior has an effect upon location decisions. This is an assumption created by the standard urban model which proposes that households' minimization of housing and commuting costs will reach location equilibrium, given the distribution of housing, and workplace locations; thus, housing and job distribution will affect the equilibrium cost-minimization location. In other words, empirical evidence on the assumption of commuting cost minimization behavior would confirm the effect that land use pattern has upon commuting.

Hamilton (1982) first examined the effect of land use pattern on commuting, by estimating the 'wasteful' commute based on the mono-centric model. In a sample of 14 cities, he estimated that almost 90% of commuting was wasteful, a finding which challenges both the traditional explanations of location decisions, and the implied land rent and land gradient distribution. If his observations are correct, then the

high land price and density near the central business district (CBD) could no longer be explained by the driving force of residential competition for land near the CBD. This was quite a departure from previous studies.

Using actual urban structure, and the highway network in 25 US metropolitan areas, White (1988) estimated that only 11% of commuting was 'wasteful'. She applied a linear programming approach to calculate the minimization of average commuting costs obtainable by reassigning workers to housing locations, in accordance with housing and workplace distribution. Using a similar technique in Boston, although essentially based on distance, Hamilton (1989) found an excess commute of 47%. He identified two potential sources for the discrepancy between White's estimates and his own findings: (i) estimate biases and (ii) the different linear measurement of the commute in each of the studies.

Cropper and Gordon (1991) used housing location reassignment to minimize costs in the Baltimore metropolitan area, but this was subject not only to land use pattern, but also to a constant utility level. Their findings of an excess commute of 50–64%, once again suggested that actual commuting is longer than that predicted by the behavioral assumption of cost minimization given the actual urban structure.

Using disaggregated data for Los Angeles County, Small and Song's (1992) study, based on both time and distance, identified excess commutes of 66 and 69%, respectively. Their work was an attempt at resolving the ongoing debate, and provided empirical evidence that the requisite commute was virtually the same, irrespective of whether the commutmg costs were measured by time or distance. They suggested that different structural assumptions were the basis of the contradictory findings in Hamilton's (1982) and White's (1988) measurements of 'excess' commute; their findings had each implied different things. Hamilton's observations investigated the assumption of the mono-centric model, whilst White's approach investigated the traditional assumption of cost minimization, given the pattern of land use. Notwithstanding the differences in fundamental assumptions, the differences in sources of data and geographical study regions are also important. Small and Song's (1992) findings demonstrate that the standard mono-centric model is overwhelmingly rejected by commuting observations in Hamilton (1982), whilst the minimization of commuting cost behavior is tested and brought into question in White (1988).

Giuliano and Small (1993) concluded that this excess commuting evidence provided the strong suggestion that there were other, more important factors to location decisions than just commuting costs. This argument again questions the assumption of cost minimization in residential decision-making, and also imports considerable uncertainty into the relationship between commuting and urban spatial structure. Using a similar methodology to Small and Song (1992), Merriman *et al*. (1995) found little evidence of excess commuting in Tokyo. In somewhat surprising contradiction to Small and Song's findings, they found evidence that the decentralization of jobs or the centralization of residences, would result in a reduction in commuting time. Clearly the balance between jobs and housing is an important factor in commuting behavior in Tokyo. This apparent discrepancy between the Merriman *et al*. (1995) and Small and Song (1992) studies, may be the result of differences in the urban structure, the methodologies used and the data sources, however, this is not explored or discussed in their work.

Frost *et al*. (1998) examined the rate of excess commuting in a selection of large British cities during 1981 and 1991 and found that the ongoing transformation of urban areas strongly affected the length of journeys to the workplace. Their findings of excess intra-city commutes (excluding inward commuters) were almost twice the

level of excess inter-city commutes (including inward commuters). Estimated excess commutes are, however, highly sensitive to the position of city boundaries.

Overall, there is a general marked contrast between the results reported by Hamilton (1982) and White (1988). Small and Song (1992) argued that the discrepancy between their works could be explained by the differences in methodologies and sources of data used. In Giuliano and Small (1993) it was proposed that in location decision-making, the cost of commuting was not the major factor, however, the later studies in Tokyo (1995) and in various cities in Britain (1998) both revealed relatively lower excess commutes, each one reaching contradictory conclusions to the Giuliano and Small (1993) study.

The Job/Housing Balance Approach

The works on job/housing balance attempt to directly investigate the relationship between commuting and land use pattern. Nowlan and Stewart (1991) used data on central Toronto between 1975 and 1988 to examine the effects of a reduction in job/housing imbalance on peak-hour work trips, and found that the construction of new housing near the workplace could reduce peak-hour work trips. Cervero (1989) used the 1980 census tracts in the San Francisco Bay Area, and data from other suburban employment centers across the United States, to investigate whether job/housing imbalances existed, and if so, whether they caused excess commutes. He found the relationship was barely significant. Giuliano and Small (1993) investigated the same question in a regional study of Los Angeles, the US's second-largest Consolidated Metropolitan Statistical Area, using 1980 journey-to-work information for 1146 zones. They found that the job/housing balance, measured by the ratio of resident workers per job, does have a statistically significant, but not excessive, influence on average commuting time. They also concluded that policies aimed at changing the job/housing balance would have only a minor effect on commuting.

Cervero (1996) found that job/housing balance does not necessarily result in a reduction in work commuting in the Bay Area. Peng (1997) identified a non-linear relationship between the job/housing ratio, vehicle miles traveled, and trip length in the Portland metropolitan area, suggesting that a jobs–housing policy would have a limited impact on vehicle miles traveled. Levine (1998) came to the same conclusion, that such policies have little impact on commuting, and that job/housing balance has no real significance in reducing congestion.

With improvements in technology and transportation facilities, there is a corresponding decrease in unit commuting cost. Consequently, there is a relative diminution in the weight of commuting costs as a factor in residential costs, when compared to the weight of land price. The decline in unit commuting cost as a result of technological advancement reduces the relative weight of commuting costs in household's residential decision-making. Furthermore, a reduction in transport costs reduces the value of accessibility, with a consequent expansion of the metropolitan area boundary, and reduction in land prices. The weighting of both commuting costs and land prices in residential choices should, therefore, be varied by the unit commute cost and unit land price. It seems too strong to state emphatically the inadequacy of the assumption of cost minimization in the standard model based on empirical evidence. Actual commuting costs may not be minimized given the land use pattern, without the utility constraint. It might therefore, be more appropriate to state that all the evidence suggests the relatively small weight of commuting costs. However, this is not an assumption of global value, either in terms of time or location; it is

local. It may not stand up over time, or in under-developed countries where unit commuting costs are high.

This argument, in which findings from the empirical works suggest a barely significant relationship between commuting and job/housing balance, should not necessarily bring into question the assumption of cost minimization behavior. It should only suggest the diminution in weighting of commuting costs in residential costs. There is also evidence to suggest that other factors can affect residential behavior in modern cities, such as household characteristics, preferences and location amenities (Giuliano, 1989; Lowry, 1988; Wheaton, 1979). The inclusion of these factors in the standard model may well produce a more appropriate model for describing residential behavior in modern cities.

Empirical Results

Our study area lies within the confines of the Taipei metropolitan area, as defined by the Transportation Institute of the Ministry of Communications (see Figure 1). The area consists of 148 traffic zones within 30 municipalities. We use data from the 1990 survey of Taipei Metropolitan Residents Commuting Flow undertaken by the Transportation Institute of the Ministry of Communication. Taipei's major industry is the service industry and there is no significant centralization of employment. Residential clusters are distributed quite evenly throughout the Taipei metropolitan region. The data includes aggregate commute flows from one traffic zone to another.

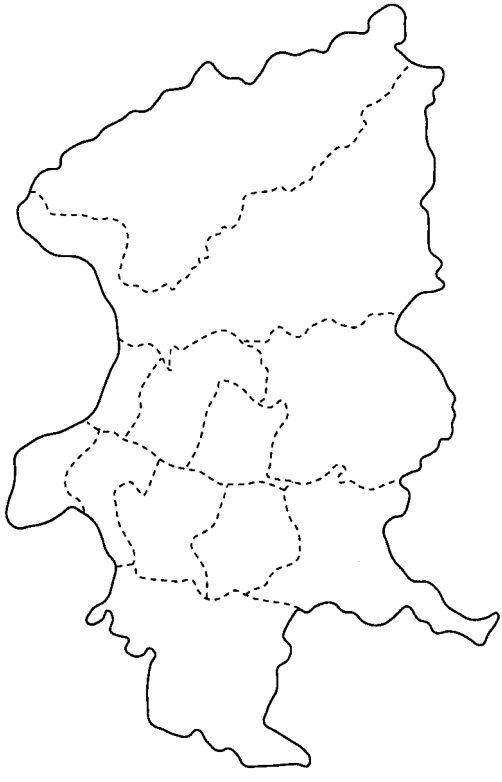

Figure 1. The Taipei metropolitan area.

The methodology used in this analysis follows the methodology adopted in Small and Song (1992), minimizing aggregate commuting costs given the distribution of housing and job locations. We apply linear programming to the existing distribution of housing and workplace locations, and reassign workers to housing locations so as to minimize the commuting cost. The average minimized commuting cost is defined as the required commute, and the ratio of the difference between the required and the actual commute is defined as the excess commute.

The estimated required mean commuting distance in the Taipei metropolitan area is 0.58 miles; the actual average commuting distance is 2.87 miles; the excess commute, in percentage terms is 79.85%. Motorcycles and buses represent the major transportation mode in Taipei and congestion problems are commonplace during rush hours in most parts of the metropolitan region. It is not considered appropriate to change the required commuting distance and actual commuting distance into commuting time using average driving speed. In the comparison with the results of Small and Song (1992) using 1980 data in the Los Angeles metropolitan area, the mean required commute distance is 3.10 miles, the average actual commute is 10.03 miles, and the excess commute is 69.1%. The excess commute in the Taipei metropolitan area in 1990 is higher than the excess commute in 1980 in the Los Angeles metropolitan area.

The estimated required commute and the excess commuting distance per municipality, are both presented in Table 1. The ratio of resident workers to jobs represents the degree of job/housing imbalance and no clear negative relationship is demonstrated between job/housing imbalance and the required commute. We attempt to explain the actual commute using two measures: the required commute to a job location, and the ratio of resident workers to jobs.

In Table 2, regressions (1) and (2) use the municipalities as the unit of analysis. Regression (3) uses traffic zones as the unit of analysis. These show the negative relationship between the worker–job ratio and the average commuting distance. The size of the coefficient is not large; it is, nevertheless, significant.

Comparison between Taipei, Tokyo and Los Angeles Regions

A comparison of the excess commute results between Taipei and the two other regions of Tokyo and Los Angeles is summarized in Table 3. Small and Song (1992) found a 69% excess commuting distance in the 1980 data on the Los Angeles–Long Beach metropolitan area, whilst Merriman *et al.* (1995) found a 15% excess commute in the 1985 data covering the Tokyo metropolitan area. The actual average commuting time in Tokyo was more than twice that of the average commute in Los Angeles, even though both metropolitan areas are of a similar size. The actual average commute in Taipei is less than one-third the distance of the average commute in Los Angeles, although this is not surprising, given that the size of the Taipei metropolitan area is only one-sixth the size of the Los Angeles area. The actual average commute in Tokyo was the largest among all three regions. However, the commuters in the Tokyo metropolitan area demonstrated the least 'wasteful' commuting among the three regions. The results suggest that 'waste' amongst commuters in both Los Angeles and Taipei was around five times greater than Tokyo commuters. There are some possible reasons for this wide variation. First of all, there are differences in the degree of aggregation in the three studies. The data used in the Los Angeles and Taipei studies were more disaggregated than those used in the Tokyo study. The excess commute in Tokyo is far less than in both Los Angeles and Taipei, and this

Table 1. Required and actual mean commuting distance

Municipality	Resident workers per job	Required (miles)	Actual (miles)	Excess (%)
(1)	0.34	0.14	2.82	94.9
(2)	0.99	0.18	2.64	93.3
(3)	0.52	0.23	2.28	90.1
(4)	0.99	0.41	2.66	84.5
(5)	0.95	0.71	3.17	77.8
(6)	0.60	0.19	2.50	92.4
(7)	0.30	0.17	2.47	93.0
(8)	0.43	0.22	2.44	90.1
(9)	1.62	0.60	3.37	82.2
(10)	1.69	0.77	3.24	76.4
(11)	2.16	0.82	3.27	75.0
(12)	3.52	0.59	2.82	79.0
(13)	1.18	1.28	3.60	64.5
(14)	2.38	0.39	2.59	85.1
(15)	1.24	0.51	2.85	82.0
(16)	1.44	0.49	2.52	80.5
(17)	1.09	0.53	2.27	76.5
(18)	1.63	0.60	2.08	71.4
(19)	0.99	0.66	2.92	77.5
(20)	0.62	1.73	4.24	59.1
(21)	1.90	2.23	6.14	63.6
(22)	1.21	2.52	5.41	53.4
(23)	1.10	1.97	4.30	54.1
(24)	1.07	1.18	4.15	71.7
(25)	0.67	1.19	3.64	67.3
(26)	0.87	1.15	3.53	67.3
(27)	1.18	2.61	6.26	58.4
(28)	1.47	3.21	5.98	46.3
(29)	1.86	4.77	9.71	50.9
(30)	6.36	3.57	6.04	40.8
Regional total	1.00	0.58	2.87	79.9

Table 2. Regression results

Type of observation	Municipality		Traffic zone
Number of observations	30	30	148
Regression number	(1)	(2)	(3)
Regression coefficient:			
Constant	2.06[a]	2.21[a]	2.19[a]
	(16.93)	(16.35)	(43.33)
Required commute distance	1.40[a]	1.43[a]	1.29[a]
	(18.97)	(19.0)	(22.96)
Resident workers per job	− 0.16[a]	− 2.08	
Adj. R^2	0.93	0.93	0.78

[a]Significant at the 5% level, two-tailed test. *t*-statistics are in parentheses.

may be due to the relatively larger area of the unit zone in Tokyo. The larger the area of the unit zone, the greater the disregard of actual inter-zone commuting; as a result, there is a much smaller gap between the actual and the required commute, thus, a much lower excess commute is indicated. One explanation for the much larger

Table 3. Comparison of Taipei, Los Angeles and Tokoyo regions

	Los Angeles	Tokyo	Taipei
Research	Small and Song (1992)	Merriman *et al.* (1995)	This study
Area	Los Angeles–Long Beach metro area	Tokyo metro area	Taipei metro area
Date of data	1980	1985	1990
Required commute (average)	3.10 miles 7.59 min	0.58 miles 42.46 min	
Actual commute (average)	10.03 miles 22.06 min	2.87 miles 49.84 min	
Excess commute	69.10% (distance) 65.60% (time)	79.85% (distance) 15.00% (time)	
Population (millions)	10.6	29.1	4.97
Jobs (millions)	4.59	13.98	1.86
Population density (per square mile)	2997	8998	8922
Job density (per square mile)	1298	4322	3339
Study area (square miles)	3536	3234	557
Average size per zone (square miles)	3.09	15.44	3.77

actual average commute in Tokyo, as compared to both Los Angeles and Taipei, might be the difference in characteristics of the commuting data. The data used in the Tokyo study involved door-to-door commuting time, while commuting data used in both the Los Angeles and Taipei studies, measured the over-the-road traffic time and distance. A measure of door-to-door commuting will always be greater than over-the-road commuting for the same commute and this may well explain the significantly greater actual average commute in Tokyo in comparison to Los Angeles and Taipei.

In comparison to Los Angeles, both Tokyo and Taipei have much higher population density and employment density. The population densities in both Tokyo and Taipei are very similar, whilst the employment density in Tokyo is around 20% higher than in Taipei. However, Tokyo is a much larger metropolitan area than Taipei in terms of the region's geographical size; Tokyo is around 5.7 times the size of Taipei. Nevertheless, despite the similar population size, the similar employment distribution structure, and the much larger geographical size of the Tokyo metropolitan area, commuters in Tokyo still managed to demonstrate much lower excess commutes than Taipei commuters.

Although the difference in the degree of aggregation is clearly an important factor, further explanations are worth considering, that is, the transportation modes and the land use patterns. Tokyo residents are highly dependent upon public transport, whereas there is relatively little reliance on such modes of transport in Los Angeles as residents there depend heavily on private means of transport. The public transportation system in Taipei is more convenient than in Los Angeles, but not as convenient as that in Tokyo. In 1990, the public transportation system, comprising primarily of buses, was the major transportation mode in the Taipei metropolitan area; the subway and monorail Mass Rapid Transit system had not been built at that time. Traveling by bus was not very comfortable or convenient, due to the problems of congestion and the limited route distribution. Taipei residents depend upon buses, motorcycles and private cars for their daily commuting, a balance between both public and private means of transportation, as compared to the Tokyo residents' reliance on public modes of transportation. Furthermore, the

neighborhoods of Taipei and Tokyo are more heterogeneous, relative to Los Angeles; in other words, jobs and housing are more closely entwined in Taipei and Tokyo than in Los Angeles. Also, the relatively longer average job tenure, and sufficiently homogeneous quality of schools in Japan, provide further considerations for Japanese workers when seeking to optimize their residential location.

The difference in urban structures in the three metropolitan areas is also an important factor in commuting. Giuliano and Small (1991) characterized the 1980 Los Angeles metropolitan region as a polycentric urban structure. Chen (1997) also characterized the Taipei metropolitan region of 1990 as a polycentric urban structure. Employment centralization in the Tokyo metropolitan area demonstrates a quite different urban structure to that of Taipei and Los Angeles. Merriman *et al.* (1995) found that both the centralization of suburban residents, and the decentralization of jobs were effective policies in Tokyo's attempts at reducing commuting, implying that Tokyo's urban structure was closer to a mono-centric form. The greater size of the metropolitan region, and the apparent mono-centric urban structure could provide an explanation for Tokyo's relatively longer actual commute time. Excess commutes were larger in the polycentric structured regions.

Hamilton (1982) calculated excess commutes based on the assumption of mono-centricity in 21 Japanese cities. The mean optimal commute was 1.83 miles, and the mean actual commute was between 6 and 10 miles. The estimated excess commute was around 70–77%. Hamilton did, however, offer this observation with some caution, given that the data in respect of the Japanese cities were not as comprehensive as the US data. Hamilton's results in the Japanese cities demonstrated excess commutes which were much larger than in the Tokyo results. The difference between these two studies might be due to the following: (i) the different approaches: Hamilton's work was based on the mono-centric city assumption, whilst the Tokyo results were derived using actual urban structure and network. There may also be bias in the approach adopted in Hamilton's work. (ii) Hamilton's results were derived from an average of 21 Japanese cities; the size of Tokyo in 1985 was much larger than the average size of these 21 cities prior to 1976. The required commute in Tokyo is, therefore, also much greater than the average in these 21 cities; the longer the actual commute, the less incentive there is to make them even longer, thus, the lower the level of excess commutes.

Conclusion

In contrast to the previous studies, the Tokyo and British studies estimated a relatively lower percentage in excess commutes, suggesting that job/housing balance policy can significantly reduce commuting time. This finding shows that the different structure or characteristics of cities may lead to different levels of excess commute; consequently, the inadequacy of the job/housing policy is not a universal phenomenon. 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. Commuting costs do play an important role in location decision-making and land use patterns also explain commuting behavior. Policies which are aimed at changing the jobs/housing balance will have a significant effect on commuting. However, regions with polycentric urban structures, and less inward inter-city commuters, demonstrate much higher percentages of excess commutes according to the empirical results. The large gap between the required and the actual commute suggests an assumed relationship

between commuting costs and location decisions. The different empirical findings each show that there are many factors involved in residential location decisions; commuting cost is just one of them. The structures and characteristics of regions vary the weight of each of the various factors in location decision-making. The more centralization of employment, and the more inward inter-city commuting, then the higher the weighting that will be attributed to commuting costs in location decision-making.

Our findings suggest that job/housing balance, measured by the ratio of resident workers per job, has a significant but not excessive influence on the actual commuting distance in the Taipei metropolitan region. Furthermore, the 79.85% excess commute implies the questioning of the assumption in commuting cost mininimization behavior. These results are similar to Small and Song's (1992) findings for the Los Angeles metropolitan region. They concluded that the large excess commutes suggest that the standard urban economic location analysis does not provide adequate explanations, and that job/housing balance has little influence on commuting patterns. The traditional location theory, which suggests that the trade-off between land costs and commuting costs is the major determinant in residential location decision-making, has also been brought into question.

Nevertheless, we have a different point of view: both the minor influence on actual commuting from the job/housing balance, and the large excess commute, do not sufficiently demonstrate that the standard location theory fails to adequately explain actual location or commuting patterns.

We do not consider it appropriate to conclude that the 'cost minimization' behavioral assumption is inadequate, due mainly to the large gap between minimized cost commuting and actual commuting. It is also inappropriate to conclude that job/housing balance has a minor influence on actual commuting costs, without considering the same utility level, when estimating minimized cost commuting. In making assumptions on cost minimization behavior, implied from the utility maximization assumption, fixed utility levels are somewhat crucial. In the previous excess commuting studies, the redistribution of the residents' job site solely to minimize commuting costs, without considering the utility constraint, could well lead to a biased result.

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