CENTRIFUGAL RELOCATION AND
BACK-COMMUTING FROM THE
METROPOLITAN FRINGE

By John R. Miron*

INTRODUCTION
Almost by definition, the spatial pattern of commuting in a metropolitan region can be viewed as the outcome of processes that have shaped the locations of residences and work sites. This idea is the basis of, for example, those “trip distribution” models in which the flow of commuters from a residence zone to a work zone is related to the relative numbers of residence sites at the origin and of worksites at the destination, and to the distance or travel time separating the zones. However, those models are essentially static. They ignore the idea that residences and jobs move over time and that their rates of movement may themselves affect the pattern of commuting.

This paper focuses on a particular kind of residential movement termed “centrifugal relocation”: the movement of individuals from inner areas to residences in the metropolitan fringe. This outward movement of households is an important part of the process by which metropolitan regions in North America and elsewhere have grown in population and in area. The paper examines the impact of recent centrifugal relocation on commuting patterns emanating from the metropolitan fringe.

Evidence is presented to show that recent centrifugal migrants are much more likely to commute back to an inner metropolitan area than are longer-term fringe residents. This evidence consists of data for the Toronto metropolitan area in 1964. Commuting flows have been disaggregated by duration and previous place of residence. Where this is not possible, the impact of centrifugal relocation is estimated by means of an augmented trip distribution model; this method is applied to both 1964 and 1971 commuting flows for Toronto.

Traditionally, studies of the journey to work have tried to isolate groups of individuals with distinctive commuting patterns.¹ Groupings have been made by

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¹ Among the early works in this field are Liepmann (1944), Carroll (1949), and Lapin (1964). More recent examples are Gera et al. (1978) and Manning (1978).
occupation, income, sex, family or household headship, and place of residence (e.g., central city or suburbs). Various attributes of the typical journey to work, such as travel time, distance and mode, have been analysed for each group. These studies have been valuable, but they have not generally considered grouping by the incidence of recent residential relocation. Evidence is presented here to suggest that that may be as important empirically as any previously considered grouping.

Why is the study of centrifugal relocation so important? There are at least three principal reasons. First, though centrifugal relocation is only a proportion of all residential movement at any time, it tends to be associated with many of the longer journeys to work. Some evidence of this is presented below. There should thus be changes in the overall average distance commuted when the volume of centrifugal relocation changes. If it declines, for instance, the average journey to work in a region should shorten.

This leads into the second reason why centrifugal relocation is important. In North America, substantial shifts are now taking place in the prospects for population growth of large metropolitan areas. The tail end of the 1945–1960 “baby boom” is now reaching adulthood. For most metropolitan areas, this coincides with net immigration levels (inflows less outflows) which have typically been falling, or even turning into net emigration. With the further maturing of the baby boom over the next two decades, the number of young adults will decrease rapidly; and it is young adults who traditionally are most likely to move. Therefore the volume of residential relocation, and particularly centrifugal relocation, may decline sharply in the near future. The smaller number of recently-arrived fringe residents should in turn bring about a substantial change in overall commuting patterns.

A third reason for the importance of centrifugal relocation is the dynamics of residence and jobsite changes and their impact on commuting. Most previous empirical work, as argued above, has in practice viewed commuting in static terms, though lip service is often paid to dynamic processes shaping it. The present study can also be viewed as static because it does not trace or model the time paths of jobsites, worksites, and commuting trips for individual workers. Rather, it looks at the commuting pattern of those who have moved recently, compared to that of those who have not. However, the present study moves commuting research closer to a dynamic framework by suggesting how commuting patterns might change in response to a change in the amount of residential relocation.

In Section 1 below arguments are presented to show why centrifugal relocation has been important in metropolitan areas and why newly-arrived fringe residents typically have to commute further than longer-term or inner area residents. Section 2 considers some earlier related work on commuting. An empirical study of the commuting behaviour of recent movers in the Toronto metropolitan area is discussed in Section 3. Data there are drawn from a 1964 home interview survey. In Section 4 a simple measure of the impact of residential relocation on commuting is introduced into a common trip distribution model and estimated, using both 1964 and 1971 data for the Toronto metropolitan area. Finally, some conclusions are presented in Section 5.

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2 The evidence presented in this paper does not measure distances travelled by commuters, but instead takes as a rough proxy the extent of their crossing of boundaries between municipalities.
1. WHY DOES RELOCATION AFFECT COMMUTING?

Consider a typical household changing its place of residence within a metropolitan area. What is likely to happen to the journeys to work of individual workers within that household? In principle, a commuting trip could become either shorter or longer; this will depend on where the new residence site is in relation to the worksite and on whether the jobsite changes in conjunction with the change in residence. It is difficult to tell anything a priori about how a typical commuting trip length might change with any move.

However, the spatial pattern of development in many large North American cities makes the impact of certain kinds of relocation somewhat more predictable. Most metropolitan areas have just come through several decades of sustained population growth: growth which typically has only recently begun to slow down. Further, the accommodation of this growth has taken place primarily in the metropolitan fringe. Thus, the typical young household looking for a dwelling has had a limited choice. Little new housing has been developed in inner city areas, and much of this has been geared to specific groups such as persons living alone. Further, relatively little existing housing in inner areas and older suburbs has come available, because rapid growth in earlier decades has meant that many dwellings there are occupied by older, less residentially mobile people. Thus the young new household typically finds few housing opportunities elsewhere than in the fringe. This generates centrifugal relocation.

Some evidence for the Toronto CMA is presented in Table 1. The number of household heads in 1976 in each Statistical Area (S.A.) is disaggregated by the 1971 place of residence.\(^3\) The dominant inter-S.A. relocation flows are outward-bound: from the central Toronto S.A. to all others, and from any other S.A. to the next-further-out neighbours. Of course, residential relocation includes intra-S.A. movers as well as inter-S.A. migrants: intra-S.A. movers are included in the diagonal entries of Table 1 along with non-movers, and are not separately identifiable here. Nevertheless, centrifugal relocation is numerically quite substantial and merits consideration on its own.

When a household moves to the fringe, long commuting trips are often the result. While jobs have been decentralising quickly within metropolitan regions in recent decades, there is evidence that residences have been decentralising even faster.\(^4\) Thus, though the fringe resident may not necessarily face a commuting trip back to the central business district itself, he or she will typically face a commuting trip which is at least in that direction. This trip will commonly be longer than it was before, if the worker has moved from a more central location.

At the same time, this process does not end with the move of a residence site to the fringe. Even if the worker never again has a change of residence, he or she may well be expected to change jobs from time to time. In view of both the continued spatial decentralisation of jobs over time and the individual benefits of a shorter journey to work, commuting trips may become shorter as length of residence in the area

\(^3\) A Statistical Area is an agglomeration of one or more municipalities. A list of the municipalities making up each S.A. is available on request.

\(^4\) One such piece of evidence is presented in Mills (1972), 40–50.
<table>
<thead>
<tr>
<th></th>
<th>1971 S.A. of Residence</th>
<th>1976 S.A. of Residence</th>
<th>North York</th>
<th>St. Clair</th>
<th>Etobicoke</th>
<th>Pickering</th>
<th>Yorke</th>
<th>Aurora</th>
<th>Altona</th>
<th>Mississauga</th>
<th>Oakville</th>
<th>Elsewhere</th>
<th>Total Heads</th>
</tr>
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<tr>
<td>Toronto</td>
<td>2,604,200</td>
<td>10,640</td>
<td>6,580</td>
<td>1,160</td>
<td>1,490</td>
<td>330</td>
<td>30</td>
<td>90</td>
<td>45</td>
<td>1,030</td>
<td>1,530</td>
<td>54,455</td>
<td>318,785</td>
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<td>1,480</td>
<td>2,050</td>
<td>1,750</td>
<td>1,150</td>
<td>180</td>
<td>70</td>
<td>20</td>
<td>1,320</td>
<td>2,230</td>
<td>32,720</td>
<td>176,090</td>
</tr>
<tr>
<td>Scarborough</td>
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<td>3,430</td>
<td>1,380</td>
<td>2,050</td>
<td>1,750</td>
<td>1,150</td>
<td>180</td>
<td>70</td>
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<td>1,320</td>
<td>2,230</td>
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<td>118,060</td>
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<td>5,910</td>
<td>1,210</td>
<td>2,380</td>
<td>3,980</td>
<td>6,885</td>
<td>1,980</td>
<td>1,400</td>
<td>450</td>
<td>25</td>
<td>1,450</td>
<td>2,290</td>
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<tr>
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<td>80</td>
<td>1,490</td>
<td>1,750</td>
<td>1,150</td>
<td>180</td>
<td>70</td>
<td>20</td>
<td>20</td>
<td>1,320</td>
<td>2,230</td>
<td>32,720</td>
<td>31,005</td>
</tr>
<tr>
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<td>145</td>
<td>1,750</td>
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<td>180</td>
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<td>15</td>
<td>1,320</td>
<td>2,230</td>
<td>32,720</td>
<td>31,005</td>
</tr>
<tr>
<td>Inner York</td>
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<td>145</td>
<td>1,490</td>
<td>1,750</td>
<td>1,150</td>
<td>180</td>
<td>70</td>
<td>20</td>
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<td>31,005</td>
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<td>1,750</td>
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<td>31,005</td>
</tr>
<tr>
<td>Albion</td>
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<td>145</td>
<td>1,490</td>
<td>1,750</td>
<td>1,150</td>
<td>180</td>
<td>70</td>
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<td>1,320</td>
<td>2,230</td>
<td>32,720</td>
<td>31,005</td>
</tr>
<tr>
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<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
<td>135</td>
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<td>135</td>
<td>135</td>
<td>4,545</td>
<td>11,345</td>
</tr>
<tr>
<td>Oakville</td>
<td>360</td>
<td>135</td>
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<td>135</td>
<td>135</td>
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<td>135</td>
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<td>135</td>
<td>135</td>
<td>135</td>
<td>4,545</td>
<td>11,345</td>
</tr>
<tr>
<td>Total Heads</td>
<td>3,218,785</td>
<td>118,060</td>
<td>96,935</td>
<td>13,570</td>
<td>31,005</td>
<td>21,965</td>
<td>20,425</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Includes the Vaughan, Richmond Hill, and Markham S.A.s.
* Includes the King, Aurora, Newmarket, Whitchurch-Stouffville, and East Gwillimbury S.A.s.
* Includes the Bolton, Bramton, and Toronto Gore S.A.s.
* Includes other places of residence outside of York, as well as those not reporting a 1976 place of residence.

Source: Special tabulation of the 1976 Census of Canada.
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increases. Recent centrifugal migrants thus are expected to have longer journeys to work than either the residents of the origin area or the longer-term residents of the fringe (destination) area.  

2. EARLIER EMPIRICAL WORK

Perhaps the best sources of information on the impact of relocation on commuting are (1) longitudinal surveys and (2) cross-sectional surveys which include worksite and residence-site histories for individuals. With data from such surveys, the journey to work of an individual could be studied before, and at varying times after, a residential relocation. This would provide some information on the dynamic impact of the relocation on commuting as the individual later adjusts his or her worksite.

Such surveys are typically expensive. Very few have been carried out, and many of those are based on one special group of individuals such as the employees of a firm.

Whiting (1952) executed an early project along these lines. He examined the commuting patterns of workers living in public housing projects in Chicago around 1948. In this study the journey to work pattern is linked to the places where people resided before they moved into the public housing projects. He found (1) a tendency for public housing residents to commute back to the traditional worksites associated with their old places of residence, and (2) some tendency over time for these residents to seek employment closer to their new homes. This kind of relocation is not the centrifugal pattern talked about in Section 1, but rather a relocation connected with urban renewal and slum clearance. However, Whiting’s is an initial attempt to measure the impact of relocation on commuting.

Lonsdale (1966) looked at the commuting patterns of production workers at two North Carolina industrial plants in 1964. One plant had been built in 1937 and the other in 1953. The journey to work pattern was analysed not by duration of residence but by duration of employment at each plant. He found that younger employees and those hired more recently tended to live further away from the plants. This, however, is again not the impact of centrifugal relocation, as one plant was located on the edge of a town of less than 30,000 population and the other was about ten miles outside the same town.

Wabe (1967) surveyed in 1964 the then-current employees of a firm of engineering consultants who in 1962 had moved their offices from central London about 15 miles to Epsom. He compared the journey to work distances before and after the move for workers still with the firm on the survey date. The typical commuting trip was found

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5 It may be important here to distinguish between those longer-term residents who were once centrifugal migrants themselves and those longer-term residents who were not. In the empirical work in this paper no such distinction is possible.

6 There is no information in Whiting’s paper on how soon the typical jobsite was changed after the residential relocation. The only information given is that the housing projects were built up to ten years before the survey.

7 Thus, workers who left the firm before the survey date but after the firm’s announcement of its intention to move are not included.

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to be substantially shorter after the move. Several interpretations of this finding are possible. One is that it reflects the greater decentralisation of households than of jobsites: the typical commuting distance falls as the worksite moves closer to proliferating suburban residence sites.\(^8\)

Roseman (1971) surveyed in 1968 a sample of non-salaried workers at a manufacturing plant in an Illinois SMSA. He obtained data on (1) the previous place of employment, (2) the place of residence immediately before employment at the new plant, (3) date of hiring, and (4) locations and dates of all successive residential relocations. He found that when new workers were hired the length of their commuting trips increased sharply. After the first residential move, however, the journey to work shortened again on average, although it did not again become as short as it had been at the old work-residence combination.

A final example of this type is described in Daniels (1973). He looked at a group of offices which had dispersed from central London. Some of these firms had moved less than 10 kilometres, while others moved over 500 kilometres. In general, he found that the journey to work before and after were quite mixed. Even for an office moving a short distance to an immediate suburban area, the mean trip length sometimes increased and sometimes decreased. Again, however, as with Wabe, the emphasis was on the relocation of a worksite rather than of a residence site.

An alternative to this kind of survey data is to make use of census results. A problem here is that a census does not typically enquire about residence and jobsite histories, so that the timings of changes in locations are not easily traced. An advantage of census data, however, is their universality. They are not restricted to the residents of one housing development or the employees of one or a few firms.

Goldstein and Mayer (1964) use 1960 census data for Rhode Island to investigate the impact of residential relocation between 1955 and 1960 on the journey to work pattern in 1960. Local areal units were aggregated into five types (central cities, satellite industrial cities, immediate suburbs, peripheral suburbs, and balance of state). A matrix of 1960 commuting flows among these five types was constructed. Subsequently, each flow was disaggregated by the 1955 place of residence (again one of the five types) of the commuter. Pronounced differences in commuting behaviour were revealed by this disaggregation. For example, consider those commuters who resided in satellite industrial cities in 1960. Among those who had also resided there in 1955, 55% worked there, only 18% worked in central cities. Among those who lived in central cities in 1955, by contrast, only 22% worked in satellite industrial cities in 1960 and fully 51% commuted back to central cities. The commuting patterns for these two groups are thus almost opposite in nature. On the basis of such comparisons, Goldstein and Mayer conclude that there are strong links between residential relocation and commuting behaviour.

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\(^8\) Another interpretation is that residents who were more centrally located gave up working for this firm when it moved because of difficulties in commuting to the new site. The employees remaining with the firm are then those who lived close to the new site anyway, and thus the typical commuting trip is shortened.
3. SOME EVIDENCE FROM THE TORONTO AREA

In 1964 more than 22,000 households were covered in a large home-interview survey of travel behaviour called MTARTS. It included among other data the following information about household heads: (1) current place of residence, (2) length of time at current residence, (3) previous place of residence, (4) current place of work, (5) duration of current employment, and (6) previous place of work. This survey provides an additional source of information on the impact of relocation of commuting.

Two levels of areal aggregation are used. In coding the survey results, residences and worksites are identified by traffic zones. These traffic zones were aggregated to the 39 Statistical Areas (S.A.s) shown in the hatched area of the map. For comparison, the 1971 CMA boundary is shown as a dotted line. In the second level of aggregation, these Statistical Areas were grouped into four tiers centred round Toronto: Toronto, Tier 1, Tier 2 and Tier 3. The Toronto tier consists of the Toronto S.A. alone. Tier 1 includes the Etobicoke, North York and Scarborough S.A.s. Tier 2 includes the Mississauga, Brampton, Toronto Gore, Vaughan, Richmond Hill, Markham, Ajax and Pickering S.A.s. Tier 3 covers the remaining outer Statistical Areas.

Table 2 presents data on the commuting patterns of household heads in 1964 among these four tiers. In each case, three specific groups have been identified: (1) "nonmovers", those heads reporting no change of residence in the preceding five years, (2) those heads reporting a recent move, i.e., in the last five years, and whose last place of residence was in the Toronto S.A., and (3) those heads reporting a recent move and whose previous place of residence was in Tier 1. There are some dramatic differences in commuting patterns when these three groups are considered by 1964 region of residence.

Consider first the Toronto tier. In the first four rows of Table 2, there are only slight differences between nonmovers and recent movers from elsewhere in the same tier. Those recent movers who came from Tier 1 have a slightly different pattern of commuting, which rather favours journeys to work back to Tier 1. Even here, however, the differences are small. In fact, the arguments outlined in Section 1 have nothing to say about the effects on commuting of relocation within or into the central part of the metropolis. They are statements about the impact of centrifugal relocation.

A different picture emerges when we look at Tier 1 commuting heads. Among recent movers within Tier 1, 46% commute to jobs in the Toronto region and 47% commute within Tier 1. Among the nonmovers, 54% commute to Toronto and 40% commute to jobs in the Toronto region and 47% commute within Tier 1. Among the nonmovers, 54% commute to Toronto and 40% commute within Tier 1.
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Table 2
Journey to Work Patterns of Commuting Household Heads by 1964 Place of Residence and Previous Place of Residence.

<table>
<thead>
<tr>
<th>1964 Place of Residence</th>
<th>Estimated Total Commuters</th>
<th>Proportions Commuting to</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Toronto</td>
</tr>
<tr>
<td>Toronto S.A.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Commuting Heads</td>
<td>177,400</td>
<td>0.780</td>
</tr>
<tr>
<td>Nonmovers</td>
<td>94,600</td>
<td>0.782</td>
</tr>
<tr>
<td>Movers from Toronto</td>
<td>60,500</td>
<td>0.782</td>
</tr>
<tr>
<td>Movers from Tier 1</td>
<td>9,700</td>
<td>0.758</td>
</tr>
<tr>
<td>Tier 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All commuting heads</td>
<td>178,000</td>
<td>0.530</td>
</tr>
<tr>
<td>Nonmovers</td>
<td>86,100</td>
<td>0.540</td>
</tr>
<tr>
<td>Movers from Toronto</td>
<td>33,800</td>
<td>0.604</td>
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<tr>
<td>Movers from Tier 1</td>
<td>39,800</td>
<td>0.460</td>
</tr>
<tr>
<td>Tier 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All commuting heads</td>
<td>45,700</td>
<td>0.309</td>
</tr>
<tr>
<td>Nonmovers</td>
<td>20,500</td>
<td>0.303</td>
</tr>
<tr>
<td>Movers from Toronto</td>
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<td>0.517</td>
</tr>
<tr>
<td>Movers from Tier 1</td>
<td>7,400</td>
<td>0.388</td>
</tr>
<tr>
<td>Tier 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>All commuting heads</td>
<td>70,300</td>
<td>0.068</td>
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<tr>
<td>Nonmovers</td>
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<td>Movers from Toronto</td>
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<td>0.295</td>
</tr>
<tr>
<td>Movers from Tier 1</td>
<td>2,700</td>
<td>0.243</td>
</tr>
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</table>

"Nonmovers" are those heads reporting no change of address in the preceding five years.

Previous places of residence are the regions in which heads last resided. Only household heads residing less than five years at the 1964 place of residence are included as movers.

The MTARTS home-interview survey was a stratified sample. Sample counts have been "blown-up" by relevant sampling ratios in deriving "Estimated Total Commuters" above and in computing the proportions journeying to work in each region.

"Else" includes commuters working outside the study area. Workers not reporting a regular place of work are excluded.

Sources: Estimated from the 1964 MTARTS Microdata File.

work within Tier 1. Finally, among recent movers from the Toronto region, fully 60% work in Toronto and only 35% work in Tier 1. Thus, recent movers from Toronto are much more likely to commute back to Toronto than are other commuting heads.

A similar pattern is present in Tiers 2 and 3. Here nonmovers are most likely to work within their regions of residence, with smaller numbers commuting to Toronto or to one of the other inner tiers. However, recent movers from Toronto are most likely
Table 3

Commuting Heads in Mississauga by Place of Work and Previous Place of Residence, 1964

<table>
<thead>
<tr>
<th>Place of Work (S.A.)</th>
<th>Total Movers</th>
<th>Total Non Movers</th>
<th>Previous Place of Residence (S.A.)</th>
<th>Toronto</th>
<th>Etobicoke</th>
<th>Scarborough</th>
<th>North York</th>
</tr>
</thead>
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<tr>
<td>Toronto</td>
<td>5,643</td>
<td>3,114</td>
<td>2,529</td>
<td>769</td>
<td>449</td>
<td>77</td>
<td>113</td>
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<tr>
<td>Etobicoke</td>
<td>3,904</td>
<td>1,779</td>
<td>2,125</td>
<td>255</td>
<td>556</td>
<td>26</td>
<td>108</td>
</tr>
<tr>
<td>Scarborough</td>
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<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>North York</td>
<td>1,175</td>
<td>668</td>
<td>507</td>
<td>192</td>
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<td>0</td>
<td>21</td>
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<td>Brampton</td>
<td>177</td>
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<td>55</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
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<td>Mississauga</td>
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<td>2,764</td>
<td>354</td>
<td>331</td>
<td>52</td>
<td>149</td>
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<tr>
<td>Elsewhere in Tier 2</td>
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<td>88</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td>Tier 3</td>
<td>454</td>
<td>144</td>
<td>310</td>
<td>83</td>
<td>0</td>
<td>0</td>
<td>37</td>
</tr>
<tr>
<td>Elsewhere</td>
<td>396</td>
<td>224</td>
<td>172</td>
<td>0</td>
<td>45</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>17,719</td>
<td>9,169</td>
<td>8,550</td>
<td>1,673</td>
<td>1,403</td>
<td>188</td>
<td>494</td>
</tr>
</tbody>
</table>

a Includes movers whose previous place of residence was outside Tier 1 as well as the Toronto and Tier 1 S.A.s.
b Heads of household reporting a move in the preceding five years.

Source: Estimated from 1964 MTARTS Microdata File.

to commute back there. Recent movers from Tier 1 are most likely to travel back to Tier 1 to work, though substantial numbers of them also commute to Toronto. This evidence thus also supports the argument that recent centrifugal movers tend to commute back to more central job sites.

Some additional insight is possible if Table 2 is disaggregated still further by S.A.s. The commuting patterns for heads residing in Mississauga, a fast-growing Tier 2 S.A., are presented in Table 3. Here it can be seen that in Mississauga:

(1) Among recent immigrants from Toronto, almost 46% commute back to Toronto to work, while among the remaining heads the proportion is only 30%.

(2) Among recent immigrants from Etobicoke, the next inner neighbour, almost 40% commute back there to work, while among other heads the proportion is only 20%.

(3) Immigrants from the other two more-distant Tier 1 S.A.s, Scarborough and North York, represent a "lateral" rather than centrifugal relocation; these movers have a commuting pattern which is not dissimilar to that of all heads or nonmover heads.

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(4) There are only small differences between All Heads, Nonmovers, and Movers (when not subdivided by previous places of residence), so the distinction between centrifugal relocation and other types of relocation is important in identifying groups of recent movers with distinctive commuting patterns.

It should be noted that the data in Table 3 are population estimates based on a "blow-up" of a roughly 2.5% sample of household heads. Not much reliance can thus be put, for example, on the sixth column (Scarborough), because the figure's are based on a small number of sample observations. This illustrates the enormous appetite for data that such a disaggregation of commuting data by residential history can engender. The problem of small samples at the S.A. level explains why the much larger tiers have been used in Table 2.

Does the evidence also show that a slowdown in the rate of relocation will bring about a shortening of the average journey to work, in the sense that fewer people will cross between tiers and more will commute within tiers? Here, one must be cautious in using cross-sectional evidence to look at longitudinal questions. Just because a recent mover has a different commuting pattern from a nonmover, it does not necessarily follow that, when the recent mover remains stationary for a few years, his or her commuting pattern will become like the nonmover's. However, in the absence of longitudinal data, one can only conclude that the evidence presented is not inconsistent with that assumption.

4. MODELLING THE IMPACT OF CENTRIFUGAL RELOCATION

A transport demand analyst might well ask two questions at this point. First, why haven't more recent data been used? Secondly, how can the impact of relocation on commuting be allowed for in other studies where relevant available data do not include information on the residential mobility of commuters? These two questions are not unrelated. As pointed out earlier, there are very few commuting studies which include any information on residential history. Any measurement of the impact of centrifugal relocation on commuting must use one of the few survey datasets which contain the appropriate information. A corollary is that many transport planners and analysts are committed to particular study areas and datasets which do not contain that information.

A method is presented here for estimating the impact of centrifugal relocation on back-commuting which does not require data on the residence histories of commuters. It requires data only on (i) the aggregate number of commuters, \( c_{ij} \), living in each zone \( i \) and working in each zone \( j \), and (ii) the number of recent movers, \( m_{ij} \), from \( i \) to \( j \). It does not require information about how many of these commuters are also recent movers. This makes it possible, for example, to pool commuting data from a transport survey with relocation data from a census.

The method basically involves the estimation of a variant of a commonly used trip distribution model.\(^{13}\) The dependent variable is the proportion of a zone's commuters

\(^{13}\) Some related variants are found in Taaffe et al. (1963:34), Lapin (1964:127–131), Wabe (1969), Forster (1974:14) and Beesley and Dalvi (1974).
who travel to another zone to work. As in most other trip distribution models the
independent variables include a job supply variable, \( c_{+ij} \), at the destination and a
distance separation variable, \( d_{ij} \). However, in addition to these, a new independent
variable is included. This is the proportion of a zone's population or workforce which
has recently moved there from the destination zone of the work trip flow now being
considered.

The remaining discussion in this section is broken into three parts. First, a
particular empirical form of the model is estimated from the same 1964 MTARTS
dataset as was used to generate Tables 2 and 3. Secondly, the same model is also
estimated from 1971 census data for the Toronto CMA. This permits an initial crude
assessment of the temporal stability of the model. Finally, a discussion is presented of
some of the pitfalls and problems of this approach to estimating the impact of
centrifugal relocation.

4.1 Model Estimation using 1964 MTARTS Data

Model and Method

In estimating this model, the journey-to-work flows for individual traffic zones
developed by MTARTS have been aggregated to flows among the 39 Statistical Areas
in Toronto, as outlined earlier. The 35 fringe S.A.s which make up Tiers 2 and 3 are
treated as the areas of interest. The commuting flows from these 35 S.A.s to each of
the four inner S.A.s (Toronto, Etobicoke, North York and Scarborough) are the
dependent variable values. Thus there are \( 35 \times 4 = 140 \) values with which to estimate
the model. The form of the model is as follows:

\[

c_{ij} = \text{the number of household heads in 1964 in fringe area } i \text{ who commute to inner area } j,
\]

\[
c_{i+} = \text{the number of heads in 1964 in fringe area } i \text{ who commute to a jobsite anywhere within the study area (i.e., Toronto, Tier 1, Tier 2 or Tier 3),}
\]

\[
Y_{ij} = \left( \frac{c_{ij}}{c_{i+}} \right) \times 100,
\]

\[
X_{1,ij} = \text{approximate shortest centroid-to-centroid distance from fringe area } i \text{ to inner area } j \text{ along existing road routes (in kilometres),}
\]

\[
m_{ji} = \text{the number of heads in fringe area } i \text{ in 1964 who reported a move in the preceding five years and whose previous place of residence was in the inner area } j,
\]

\[
h_i = \text{the total number of heads in fringe area } i \text{ in 1964,}
\]

\[
X_{2,ji} = \left( \frac{m_{ji}}{h_i} \right) \times 100,
\]

\[
X_{3,j} = \text{the total number of household heads (in hundred thousands) in the study area with jobs in inner area } j, \text{ and}
\]

\[
v_{ij} = \text{a random error term.}
\]

The following nonlinear version of the model was employed:

\[
Y_{ij} = B_0 X_{1,ij}^{r_{1}} e^{b_{i} X_{2,ji} X_{3,j}} e^{v_{ij}} \quad (1)
\]

If \( B_2 = 0 \), (1) reduces to a commonly used trip distribution model.\(^{14}\) In general, we

\(^{14}\) See footnote 13.

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expect \( B_1 \) to be negative and \( B_2 \) to be positive. Our hypothesis is that centrifugal relocation induces more commuting back to the inner area, and thus that \( B_2 \) is positive. Note that the centrifugal relocation variable is entered exponentially into (1). Thus, even when \( X_{2,ii} \) is zero (i.e. there is no centrifugal relocation), the rate of commuting \( (Y_{ij}) \) from the fringe is not necessarily zero.\(^{15}\)

The parameters of equation (1) were estimated using weighted nonlinear least squares. It is possible to estimate (1) by linear least squares by taking a logarithmic transformation of both sides of the equation, but that would necessitate dropping any fringe commuting flows valued at zero. In the MTARTS data set, 45 of the 140 commuting flows are zero, and 20 of the 35 fringe S.A.s have an observed commuting flow of zero to at least one of the four inner S.A.s. This is valuable information which must be discarded if a linear least squares approach is used. Under nonlinear least squares, however, these zero values can be retained. Weighting was applied to reflect the notion that the fringe areas are not of equal size. The smallest S.A. (Tottenham) had only 120 commuting heads of household in total (i.e., \( c_{ii} \)) in 1964, while the largest S.A. (Mississauga) had 17,719. The P3R computer program of the BMD (P-series) package was used in the estimation of the parameters of (1).

**Statistical Findings**

The estimated parameter values and their respective asymptotic standard deviations are presented in the first column (the 1964 MTARTS “full” model) of Table 4. There is a reasonably good fit here, as the \( R^2 \) is large. Also, all parameters are of the correct sign and apparently statistically significant. This includes the centrifugal relocation variable.

Consider what happens to the parameter estimates when the centrifugal relocation variable is dropped (that is, \( B_1 \) is constrained to be zero). The results are displayed in the second column of Table 4. The \( R^2 \) drops substantially, to 0.622. This indicates that the centrifugal relocation variable has a substantial separate effect on back-commuting, and that effect is not captured elsewhere (in the distance and job supply variables) in the model.

How sensitive is the volume of back-commuting? From equation (1), the elasticity of \( Y_{ij} \) with respect to \( X_{2,ii} \) is \( B_2X_{2,ii} \). In the first column of Table 4 the estimated value of \( B_2 \) is about 0.1. Thus, if a fringe area \( j \) has about 5\% of its heads of household in-migrating from inner area \( i \), this elasticity is 0.5; a 1\% increase in migration to the fringe implies an 0.5\% increase in back-commuting to that inner area. In our MTARTS sample of 140 commuting flows the value of \( X_{2,ii} \) ranged from 0\% to 17\% and had a weighted mean of 3.4\%.

These comments are based on the estimated coefficient of the centrifugal relocation variable and its asymptotic standard deviation. They support the contention that centrifugal relocation has an important effect on back-commuting, both in statistical significance and in numerical size.

\(^{15}\) It would have been necessarily zero if we had instead used the following model:

\[
Y_{ij} = B_0 X_{1,ij} X_{2,ji} X_{3,ij} e^{\phi v}
\]

For this reason, (1) is preferred.
Table 4
Parameter Estimates using 1964 MTARTS and 1971 Census Commuting Data

<table>
<thead>
<tr>
<th></th>
<th>1964 MTARTS</th>
<th>1971 CENSUS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FULL</td>
<td>$B_2 = 0$</td>
</tr>
<tr>
<td>$B_0$: Intercept coefficient</td>
<td>80.552</td>
<td>369.274</td>
</tr>
<tr>
<td>Asymptotic standard devn.</td>
<td>15.759</td>
<td>106.435</td>
</tr>
<tr>
<td>$B_1$: Distance coefficient</td>
<td>-0.736</td>
<td>-1.021</td>
</tr>
<tr>
<td>Asymptotic standard devn.</td>
<td>0.062</td>
<td>0.097</td>
</tr>
<tr>
<td>$B_2$: Centrifugal relocation coefficient</td>
<td>0.098</td>
<td></td>
</tr>
<tr>
<td>Asymptotic standard devn.</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td>$B_3$: Job supply coefficient</td>
<td>0.700</td>
<td>0.973</td>
</tr>
<tr>
<td>Asymptotic standard devn.</td>
<td>0.053</td>
<td>0.095</td>
</tr>
<tr>
<td>$B_4$: GO Transit coefficient</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asymptotic standard devn.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.832</td>
<td>0.622</td>
</tr>
<tr>
<td>$N$</td>
<td>140</td>
<td>140</td>
</tr>
</tbody>
</table>


Possible Statistical Problems

As with any statistical technique, we must consider problems which might make it more difficult to interpret these findings. Let us briefly examine three of these in turn: (i) the form of the model, (ii) estimation when the dependent variable is a percentage, and (iii) multicollinearity.

One might wish to argue that equation (1) is an inappropriate model form. I would disagree, on the grounds that (i) the $R^2$ is fairly high, indicating that the data overall are fitted well by this function, and (ii) the gravity model, of which (1) is an extension, has been widely used in studies of trip-making. But where does model (1) not seem to fit particular observations very well? Three S.A.s, Vaughan, Markham, and Uxbridge Twp., may be singled out here. All three have about 40% of commuting heads involved in back-commuting to the Toronto S.A., yet the model predicts only about 16% to 20%. All three have had substantial immigration from both the Toronto S.A. and the intervening inner metropolitan S.A. (Etobicoke, North York, or Scarborough), but relatively more commuting heads go back to Toronto and fewer to these other three inner areas than is predicted by the model.

Since $Y_{ij}$ is a percentage, $\sum_j Y_{ij} = 100$ when the summation is taken over all possible destinations. Ordinarily, this would require an estimation method which specifically recognises this constraint. In this paper, however, the constraint is not essential, because we consider only four specific destinations. In the Oakville S.A., for example, only about 27% of the commuting heads work in these four (Toronto, Etobicoke, North York and Scarborough) S.A.s. If we were interested in all

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commuting flows originating in, say, Oakville, a constrained estimation method would be necessary.

In comparing the coefficient estimates for the distance and job-supply variables in the first two columns of Table 4, however, one must also consider the possibility of multicollinearity. When a centrifugal relocation variable is excluded from the regression, the estimated values for $B_1$ and $B_2$ both change by about 40%. This is not surprising. As can be seen in Table 1, centrifugal relocation tends to increase with (i) the size of the population of the originating S.A. and (ii) the nearness of the fringe S.A. to the originating S.A. Thus our estimate of $B_2$ will probably be correlated with the estimates of both $B_1$ and $B_2$. That is not to say that centrifugal relocation is not important on its own; its addition to the model raises the $R^2$ from 0.622 to 0.832. What the possibility of multicollinearity does do is to make it difficult to know whether the true marginal effect of centrifugal relocation is roughly equal to, or substantially smaller or larger than, 0.098.

4.2 Model Estimation from 1971 Census Data

Model and Method

In comparing the coefficient estimates for the distance and job-supply variables in asked to indicate the municipality wherein they usually worked. A special tabulation of these census results has yielded estimates of aggregate inter-municipal and intra-municipal commuting flows. These flows were further aggregated in this study to the Statistical Area level.

To be included in the study area, an S.A. by definition had to send at least 5% of its 1971 commuting workforce to the four inner S.A.s in Toronto and Tier 1. There were 54 fringe S.A.s which satisfied this condition in 1971. These included the 35 fringe S.A.s included in Section 4.1 above, and also 19 other S.A.s (shown on the map as those outer areas which are not hatched-in). Therefore, a fringe-to-inner-area trip distribution can be estimated on the basis of $54 \times 4 = 216$ observations.

These census data enable us to estimate models very similar to (1) for 1971. The principal substantive difference is that the 1964 MTARTS data cover the commuting behaviour of household heads only, while the 1971 census data are for all commuters. To the extent that heads of household have different patterns of commuting from other commuters in general (that is, they commute longer distances), this should be reflected in the estimated parameters. Thus one might expect the distance coefficient to be smaller in absolute value when the 1964 MTARTS data are used than when 1971 data are used. However, other changes between 1964 and 1971, such as changes in relative energy costs, might mask this difference. A second consequence of using all commuters is that the definition of $X_i$ should be changed. Earlier it was the proportion of 1964 heads in fringe area $i$ who moved into $i$ during the preceding five years and whose previous place of residence was inner area $j$. Now it is the proportion of the 1971 population in fringe area $i$ (aged over 5 years) who reported their 1966 place of residence as inner area $j$. There are subtle differences between these two classes, but they are broadly similar.\(^{16}\)

\(^{16}\) Note that the job supply variable $X_{i,j}$ is now the total number of commuters reporting jobs in zone $j$ in 1971 (in hundred thousands) and not as before the number of commuting heads-of-household reporting jobs in $j$ in 1964.
Another difference between the 1964 and 1971 commuting flows is that since the mid-1960s the Government of Ontario has created and extended a system of rapid rail and express bus transit known as GO Transit. One purpose of the system has been to relieve the flow of automobiles into the downtown area of Toronto. A potential complication, however, is that GO Transit has encouraged centrifugal residential relocation and back-commuting by reducing the cost and duration of commuting below what it would have been by automobile. To allow for this, a new independent variable \( X_{a,ij} \) has been added to the model.

\[
X_{a,ij} = \begin{cases} 
1 & \text{if fringe area } i \text{ and inner } j \text{ are connected by GO Transit,} \\
0 & \text{otherwise}
\end{cases}
\]

The full model to be estimated is:

\[
Y_{ij} = B_0 X_{a,ij} e^{b_X X_{ij}} e^{b_a X_{a,ij}} e^{e_{ij}}
\]  

(2)

In this formulation, the presence of a GO Transit link implies that the incidence of back-commuting will be proportionately higher. This is a crude assumption. It could be argued, for example, that the effect of GO Transit on back-commuting will be relatively smaller for those fringe areas which are further from the inner metropolitan areas. In support of formulation (2), I would argue that (i) it is a reasonable first approximation, and (ii) the GO Transit system serves only the near fringe areas, so that its impact is more uniform than it would have been if both near and more remote fringe areas had been served.

**Statistical Findings**

Estimates for the parameters in equation (2) are presented in the third column of Table 4. These estimates are derived by weighted nonlinear least squares, as described earlier for the 1964 MTARTS data. Their most striking feature is that they are highly comparable to the first column values (the 1964 MTARTS full model). The estimated values for \( B_1 \) and \( B_2 \) are very similar in both, and so are the \( R^2 \) values. The principal difference is the somewhat smaller coefficient for the job supply variable in 1971.

As with the 1964 data, centrifugal relocation plays an important role in determining the rate of back-commuting in 1971. Its coefficient value remains at 0.1 and, as in 1964, the asymptotic standard deviation is small in comparison with this. The fourth column of Table 4 presents the coefficient estimates when centrifugal relocation is not included. The inclusion of centrifugal relocation raises the \( R^2 \) from 0.743 to 0.816, indicating again that this variable makes an important separate contribution to the rate of back-commuting.

**Possible Statistical Problems**

One might want to raise the same three issues as in the previous section on the 1964 MTARTS data findings. The following comments apply to the first and third of those: the form of the model, and multicollinearity.

It was earlier noted that in the 1964 data estimation the Vaughan, Markham and Uxbridge Twp. S.A.s had commuting flows to the Toronto S.A. which were significantly underestimated by the model. If we use the 1971 data, these three S.A.s are not outliers. In fact, there is only one small S.A. (Tottenham) in 1971 which is as badly estimated as those three were in 1964. About 24% of Tottenham's residents in

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1971 had moved there from the Toronto S.A. since 1966.\textsuperscript{17} On this basis the model predicted that 52% of Tottenham’s commuters worked in Toronto, but in fact only 17% did.

There is additional evidence of multicollinearity. In addition to its effects on $B_4$, and $B_5$ already noted, the exclusion of centrifugal relocation causes $B_3$ to change sign from $+0.105$ to $-0.120$.\textsuperscript{18} This reinforces the conclusion that we must be careful in interpreting a specific estimate of $B_3$ as the marginal effect of centrifugal relocation on back-commuting, even though it is clear that there is a pronounced and significant marginal effect.

4.3 Validity of this Approach

The use of regression-estimated models such as those in Table 4 does offer some hope to the transport analyst who cannot disaggregate his or her commuting flows by duration and previous place of residence. It makes it possible to measure the impact of centrifugal relocation on back-commuting if only aggregate commuting patterns and aggregate residential relocation patterns are known. That no knowledge of the relocation pattern of specific kinds of commuters is required is the principal merit of these models.

They have been applied with some degree of success to commuting data for Toronto in both 1964 and 1971. The results have confirmed the important role of centrifugal relocation on back-commuting. Further, there is some evidence of temporal stability, as most of the model parameter estimates did not change substantially between 1964 and 1971. At the same time, some basic differences between the two datasets make precise comparisons impossible.

There are, however, at least three important qualifications to keep in mind. The first is the problem of multicollinearity, discussed at length above. Part of the price paid for not disaggregating commuting flows by duration and previous place of residence is that the separate impacts of different explanatory variables become difficult to unravel. This has certainly been so with the 1964 and 1971 datasets used here. It may well be so with most metropolitan areas. Fringe areas with high back-commuting rates tend to be those in close proximity, and these areas often receive the greatest inflows of centrifugal migrants, many of whom come from larger inner areas. Thus, to what extent can one separate the effects of distance to an inner area, the number of jobs there (which is closely linked to size), and centrifugal relocation? This problem may make it impossible to decipher the full extent of the impact of centrifugal relocation on commuting behaviour.

\textsuperscript{17} The census in 1971 was completed principally by self-enumeration. It has been suggested that, when asked about their previous place of residence, a number of respondents gave incorrect answers. Someone moving from North York to Tottenham, for example, might list “Toronto” as the previous place of residence, meaning the “Municipality of Metropolitan Toronto”, of which North York is part. The answer would be coded, however, as the “City of Toronto” (or part of the Toronto S.A.). Part of the reason why Tottenham is an outlier in this analysis may be coding errors of this kind.

\textsuperscript{18} Note that the GO Transit coefficient is not large relative to its asymptotic standard deviation. One would not be inclined to conclude that GO Transit had a statistically significant effect on back-commuting.
A second qualification relates to the definition of what is being measured. In this model, centrifugal relocation from an inner zone \( j \) to a fringe zone affects the level of commuting back to that zone \( j \). It does not, however, affect commuting back to any other inner zone. Look back for a moment at the commuting behaviour of Tier 2 and Tier 3 (fringe) residents in 1964 shown in Table 2. Among recent centrifugal migrants who came from Tier 1 there is a strong tendency to commute back to the Toronto S.A. as well as to an S.A. in Tier 1. Similarly, recent migrants from the Toronto S.A. tend to commute back to Tier 1 as well as to Toronto itself. The model used here does not cover this. In other words, even if there were no multicollinearity, this model would not capture the entire impact of centrifugal relocation, because it ignores the effect of relocation from an inner area to a fringe area on commuting back to other inner areas.

A related third qualification concerns the size of the areal units involved. Many transport studies work at the level of traffic zones which are typically much smaller than the Statistical Areas used here. Trip distribution models are commonly used, but they are typically applied to traffic zone data. Thus, one might reasonably ask whether it matters whether traffic zone data are used to estimate a model such as (1) or (2) where centrifugal relocation is included as a variable. The answer is yes, because of the second qualification. If inner areas are defined as small traffic zones, it is unlikely that a person will live and work in the same zone. Consequently, a person moving from an inner area \( j \) to a fringe area \( i \) is unlikely to commute back to \( j \) to work. He may well be commuting back to some inner zone, but it is not likely to be \( j \). Thus the specification of areal units is very important in determining whether centrifugal relocation as measured here will have a significant impact on commuting patterns.

5. SOME CONCLUDING COMMENTS

In the preceding sections, some substantial evidence for Toronto has been presented to support the claim that centrifugal residential relocation has a considerable impact on the commuting behaviour of fringe residents. The desirability has been established of disaggregating commuting flows within a metropolitan region on the basis of duration and previous place of residence. Where a disaggregation is not possible, an alternative approach using a variant on a trip-distribution model has been suggested, and this has been estimated from 1964 and 1971 data.

Centrifugal relocation has for some time been an important part of metropolitan growth, but relatively little attention has been paid to its impact on commuting behaviour. Much attention in commuting research has been concentrated on various groups of commuters such as professionals, females, blue-collar workers, household heads and so on, or on spatial patterns of jobs and residences. This focus on what might be termed a “static” view of commuting obscures the fact that journeys to work are partly a response to the “dynamics” by which a metropolitan region grows. A corollary is that as the rate of metropolitan growth changes, so will commuting patterns, and thus a “static” view will become more and more inappropriate.
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