ABSTRACT

In most empirical studies of commuting behaviour, commuting flows are seen to be responsive to the spatial patterns of residence and work sites. Drawing upon the residential relocation literature, it is suggested that the rates of change of these spatial patterns over time also affects the pattern of commuting. An empirical investigation is described which uses data on commuting flows from fringe areas into the Municipality of Metropolitan Toronto in 1964 and 1971. Recent residential relocation is found to have a significant effect on the level and direction of commuting. Further, this effect is found to be similar in 1964 and 1971 suggesting a stability in commuting behaviour.
COMMUTING AND RESIDENTIAL RELOCATION IN THE
METROPOLITAN FRINGE

In urban transportation planning, commuting flows among zones within a metropolitan area are usually seen to be determined by a set of "static" variables. Such variables include the spatial pattern of residence sites and work sites and the costs (time, money, or both) of using the transportation system. In empirical work, the generalized gravity model is a common example of this approach.

\[ C_{ij} = a(c_{ij})^b (c_{ij})^y (t_{ij})^{-\delta} \quad i,j = 1,2,\ldots,N \quad (1) \]

where \( C_{ij} \) = number of commuters travelling from zone "i" (residence) to zone "j" (work),

\( N \) = number of zones in region,

\[ C_{i+} = \sum_{j=1}^{N} C_{ij} \quad \text{total number of workers resident at zone "i"}, \]

\[ C_{+j} = \sum_{i=1}^{N} C_{ij} \quad \text{total number of workers (resident in the region) employed at zone "j"}, \]

and \( t_{ij} \) = a generalized measure of the journey-to-work cost for a trip from "i" to "j".

It is recognized that these "static" variables may in fact be changing constantly over time. However, the implication of these "static" variables is that if they are held constant for a period of time then so would the commuting flows also remain unchanged. It is the contention of this paper that commuting flows are responsive not only to the spatial patterns of job and residence sites but also the rates and direction of change of these over time.
Researchers in the area of residential relocation have for some time emphasized the variety of factors affecting when and where a household will decide to relocate.\(^1\) The journey-to-work trip is, of course, one important determinant in the relocation decision but there are other non-commuting determinants such as changes in family life cycle status, in income, or in neighbourhood characteristics. Furthermore, this literature would suggest a two-way relationship between commuting and residential relocation. On the one hand, a substantial proportion of relocation activity is attributable to non-commuting determinants. Given that in a growing metropolitan area most of the new housing opportunities are located on the fringe and that job sites tend to be slightly more centralized, residential relocation usually implies a longer journey-to-work.\(^2\) On the other hand, some relocation activity is generated specifically because the journey-to-work is felt to be too long. In this case, long commuting trips tend to generate residential relocation.

This work on residential relocation has important implications for a generalized gravity model such as (1) above. Suppose we consider the same metropolitan area at two points in time. Suppose further that the aggregate number of residences and work sites remain constant over this time period and that the spatial patterns of each \(C_r\) and \(C_w\); are similarly fixed. The residential relocation literature

\(^1\) Refer, for example, to Quigley and Weinberg (1977).

\(^2\) Refer, for example, to Mills (1972; pages 46, 47) for evidence of the relative rates of suburbanization of residences and job sites.
would suggest that the $t_{ij}$ terms could still be changing, even if the $t_{ij}$'s remained constant, because of a continuing pattern of residential relocation among the zones. If the assumption of zero-growth is relaxed, the conclusion remains unchanged. The pattern of commuting will be responsive to the changing spatial patterns of job and residence sites. It will, however, partly also be responsive to the patterns of residential relocation helping to generate the new pattern of residence sites.

It is the purpose of this paper to attempt some crude empirical estimates of the relative contribution of residential relocation in explaining the pattern of commuting flows. Flows of commuters into the Municipality of Metropolitan Toronto in 1964 and 1971 provide the basis for these estimates. The empirical approach used involves an extension of the generalized gravity model in (1). We turn to a discussion of the empirical approach used after first assessing some alternative approaches.

1. ALTERNATIVE EMPIRICAL APPROACHES.

There are at least two approaches to an empirical evaluation of the hypothesis that recent residential relocation has a significant effect on commuting behaviour. One approach (microanalytic) would involve working directly from household or individual data. The other approach (macroanalytic) would aggregate up from the individual case and look at behaviour at the traffic zone, census tract, or municipality level. Both approaches are of considerable value in understanding commuting patterns although our subsequent analysis is restricted to the macroanalytic approach.
Under the microanalytic approach, one would be primarily interested in longitudinal survey data from a collection of representative individuals. With such data, one could examine time patterns of residential and job site location throughout a worker’s life, estimate lead or lag times between residential and job site relocation, and investigate the effects of these on the journey-to-work through the worker’s life.

Very few of these kinds of studies appear to have been undertaken and virtually all have been based on the employee records of a selected set of manufacturing firms. Lonsdale (1966) for one investigated the commuting patterns of production workers at two North Carolina industrial plants and found that, when workers change residence, the journey-to-work distance shortened considerably. Wade (1967) studied the commuting patterns of employees of a firm which had moved from London (England) to Epson and concluded that the journey-to-work time shortened. Roseman (1971) undertook a survey of new hirings at an S.M.S.A. factory. Each new worker was asked to indicate his old place of work and records were kept of the first residential move made after the date of hiring. In this study Roseman was able to calculate average distances from the old residence to the old work site (6.8 miles), from the old residence to the new work site (14.4 miles) and from the new residence to the new work site (9.9 miles). Further, Roseman was able to estimate the average time from date of hiring until first residential move (3.3 years). Finally, Daniels (1973) in a study of British officers which had decentralized from London found that the average commuting time of workers had decreased although the average distance had increased.
Under the macroanalytic approach, use is made primarily of survey data collected at one point in time. Often these data are derived from O-D traffic surveys while, for other cases, they are based on census tabulations. Because such data usually describes commuting and locational behavior at only one point in time, the empirical relationships developed generally are static. No examination is made in this case of the potential dynamic linkage between commuting and residential relocation.

One of the few exceptions to this general macroanalytic approach is the work of Goldstein and Meyer (1964). Using data from the 1960 census for Rhode Island, they investigated the relationships among 1960 place-of-work, 1960 place-of-residence, and change of place-of-residence between 1955 and 1960. Five regions were defined for the state (Central Cities, Satellite Industrial Cities, Immediate Suburbs, Peripheral Suburbs, and Balance of State). A commuting flow matrix was constructed for 1960 with the origins and destinations given by these five areas. Subsequently, each flow (for example, the commuter flow from Satellite Industrial Cities to Central Cities) was disaggregated by the 1955 place-of-residence of the worker. Very pronounced differences in commuting behavior were found based on this disaggregation. For example, among 1960 residents of Satellite Industrial Cities who had also resided there in 1955, 56.1% worked there and only 10.1% worked in Central Cities. By contrast, among 1960 residents of the same area who had lived in Central Cities in 1955, only 22.7% worked in the Satellite Industrial Cities while fully 81.1% worked in Central Cities. Thus,
the commuting patterns for these two groups are almost opposite in nature. Similar differences for resident workers in other regions of the state are observed by Goldstein and Mayer. Thus, they are able to conclude that recent (i.e. within the past five years) residential relocation has a major effect on commuting patterns.

2. THE EMPIRICAL APPROACH USED

In certain respects, the approach developed in this paper is similar to that of Wabe (1969). Wabe used data on commuter travel into Central London from 12" outlying boroughs (within thirty mile radius) in 1951 and 1961. In his multiple regression analysis, the dependent variable is the proportion \( C_{ij}/C_{11} \) of workers residing in borough \( i \) who commute to Central London (denoted as borough \( 1 \)). Wabe includes several independent variables to explain this commuting pattern: average journey time to Central London, average journey price (by rail), the ratio of local borough employment to labour force \( (C_{ij}/C_{ij}) \), a socio-economic class indicator, and a series of dummy variables reflecting ease of access to public transit facilities. Although Wabe estimated a linear model, the similarities with respect to the generalized gravity model (1) are evident.\(^3\)

\(^3\)It is interesting to note that although much is typically made of sex differences in commuting flows, Wabe's results indicate a striking similarity between male and female commuter flows. When regression equations are estimated separately for each sex, there are minimal differences between corresponding regression coefficients.
In our own work, we postulate models of the following forms:

\[ Y = f(x_1, x_2, x_3, x_4, x_5) \quad \text{and} \quad 2 \]

\[ Y = f(x_2, x_3, x_4, x_5) \quad \text{(3)} \]

where \( Y = \frac{C_{ij}}{C_{ik}} \) (commuting share)

\( d_{ij} \) = road mileage between areas "i" and "j"

\( d_{ij}^k \) = 0 if \( d_{ij} \leq d_{ik} \)
\( = 1 \) if \( d_{ij} > d_{ik} \)

\( x_1 = d_{ij} \) (distance)

\( x_2 = \frac{\sum_{k} p_{ik} c_{ik}}{C_{ik}} \) (intervening opportunities)

\( m_{ij} \) = number of persons moving from area "j" to area "i" in the past five years.

\( p_{ij}^5 \) = population aged over five years and resident at "i".

\( x_3 = \frac{m_{ij}}{p_{ij}^5} \) (residential relocation)

\( x_4 = \frac{c_{ij}}{C_{ik}} \) (job supply at "j"), and

\( x_5 = 1 \) if areas "i" and "j" are connected by on-rail transit
\( = 0 \) otherwise.

The dependent variable (Y) and \( x_1 \) are similar to Wabe's. Unlike him, however, we do not have journey time and price data and therefore rely on either mileage or intervening opportunity variables (\( x_2 \) or \( x_3 \)) to capture the effect of distance. Similarly, we have just one variable (\( x_5 \)) to represent the effect of public transit availability in fringe areas. The novel feature of our work lies in the inclusion...
of \( X \), which measures the importance of residential relocation from \( \text{"J"} \) to \( \text{"I"} \) in relation to the total population resident at \( \text{"I"} \).

Approaching the impact of residential relocation on commuting behaviour in this way is not without its problems. Principal among these, is the problem of under-estimation. Suppose we consider an individual who is living and working in area \( \text{"J"} \) in 1966 but who moves his residence to area \( \text{"I"} \) between 1966 and 1971. To the extent that he retains his old work site at \( \text{"J"} \), the commuting flow in 1971 from \( \text{"I"} \) to \( \text{"J"} \) will be sensitive to his relocation decision. Suppose, however, that this individual in 1966 had lived at \( \text{"J"} \) and worked in another area \( \text{"K"} \). Suppose also that he moves from \( \text{"J"} \) to \( \text{"I"} \) during the next five years but retains his job at \( \text{"K"} \). In this case as well, residential relocation has reshaped commuting patterns. However, models such as (2) or (3) do not detect these indirect linkages at all.

In part, this under-estimation problem can be resolved by a suitable aggregation of areal units. Working with traffic zones, census tracts, or other small areal units exacerbates the under-estimation problem by increasing the likelihood that the resident used to work outside his zone of residence. In this study, municipalities (or aggregations of these) constituted the areal units used. There still remains something of an underestimation problem but it is believed that such an aggregation provides a more suitable basis for testing models such as (2) or (3).
1. THE STUDY AREA AND DATA SOURCES

There exist two basic sources of commuting data for the Toronto area. One data set is derived from the 1971 Census of Canada. The other is taken from the 1964 Metropolitan Toronto and Region Transportation Study’s (METARTS) home interview survey. These data sets are somewhat different and we shall begin by briefly describing each.

In the 1971 Census of Canada, respondents (on a 1/3 sample basis) were asked to indicate the address of their normal place of work. This information was coded at both the street and the census subdivision (CS) level and used to construct estimates of commuting flows.\(^4\) For all CMAs in Canada, these commuting flows are provided at the inter-census-tract level based on the street-level coding of work addresses. For all census subdivisions in Canada, these commuting flows are provided at the inter-CS level based on the CS-level coding of work addresses.

\(^4\) In this study, a census subdivision is either a municipality, a borough, or an incorporated township. The two data series (street-level and CS-level) should be identical in principle. However, some respondents failed to correctly identify both the street and census subdivision of their place of work. As such, there are discrepancies between the two. This problem is most acute for flows into the city of Toronto. Commuters from other areas had a tendency to give Toronto as the census subdivision of work even though they actually worked in one of the boroughs of Toronto which are separate census subdivisions.
The inter-CS commuting flow for a region centred on Toronto constitute the data set used in this study. The inter-census-tract commuting flows were not satisfactory both because of the under-estimation problem and because the tracted CMK does not include a number of fringe areas which were just beginning to experience suburbanization in 1971. Further, there are a sufficient number of census subdivisions in the Toronto study area to make a statistical evaluation feasible.

The study area boundary was drawn to include all those census subdivisions from which at least 5% of the resident employed workforce commutes to the Municipality of Metropolitan Toronto to work. This is a generous threshold in that census subdivisions as much as 90 miles from the CBD of Toronto are included. The attached map illustrates the included area and also contrasts the study area boundary with the 1971 C.M.S. boundary (dotted line).

Within this study area, the census subdivisions were grouped into 38 Statistical Areas (S.A.'s). In many cases, the S.A. consists merely of one census subdivision. In the remaining cases, the S.A. consists of two or more S's. This aggregation is carried out for two reasons. First, since there have been numerous amalgamations, annexations, and boundary changes in Ontario municipalities since 1951, it was deemed desirable to attempt to define areal units for which data are available and for which boundaries are constant over the period of 1951-1971. This makes it possible to look at historical records for an S.A. from 1951-1971 without having to worry about the effects of boundary shifts. With the exception of one area north of Toronto, the S.A.'s defined
In this study permit this kind of historical comparison. The second aggregation carried out is the amalgamation of the City of Toronto, East York and York Boroughs. This was carried out not because of boundary changes but because of a potential error arising where Census respondents indicated "Toronto" as the place of work but in fact worked in nearby York or East York.

In addition to this 1971 commuting data, some evidence of commuting flows is available from the 1964 Metropolitan Toronto and Region Transportation Study (MTARTS). As part of MTARTS, a survey sample of approximately 2.5% of all area households was carried out. From the sample, information about the journey-to-work patterns of household heads has been collected. Using this sample data, it has been possible to estimate inter-S.A. commuting flows for 39 of the S.A.'s. The remaining 19 S.A.'s included in the 1971 study area lie outside the 1964 MTARTS study area. While recognizing that the 1971 Census commuting data covers all employed persons (versus only household heads in the MTARTS data) and 58 S.A.'s (versus 39 in MTARTS), this study permits some general comparison of the changes or stability in commuting patterns between 1964 and 1971.

The use of cross-sectional data poses problems in assessing the dynamic relationship between commuting and

5The census subdivisions making up the Regional Municipality of York were re-arranged in 1970 in a way that makes historical comparisons almost impossible for areal units other than the Regional Municipality itself.
recent residential relocation. As with Goldstein and Mayer, one is restricted in the Census to data which are based on the place of residence five years before (i.e. June, 1966). Thus, for each S.A., the proportion of residents (aged five years or more) who moved there from any other S.A. during the past five years can be calculated.

A similar kind of variable describing recent residential relocation can be constructed from the 2.5% MTARTS sample. In that survey, household heads were asked how long they had lived at their current place of residence and where they had lived preceding that. This data has been transformed in this study to make it more-or-less comparable with the Census question on migration. Those household heads who had changed their S.A. of residence within the preceding five years (1959-1964) are classified by their previous S.A. of residence. There are two differences here from the 1971 Census notion of migration. First, the MTARTS data refer only to household heads and not to the entire population aged five plus. Secondly, the MTARTS data are based on where the person lived previously and not where he lived exactly five years before. The two data sets are somewhat comparable but some distinctions between them are plainly possible.

Information has also been assembled on inter-S.A. distances. Using a map of King's (First Class) Highways and secondary roads for Ontario in 1971, minimum distances were calculated between all pairs of Statistical Areas. In all cases, this involved manually designating a centroid for the S.A. (the centre of the largest population concentration), calculating a minimum distance to a highway or secondary road system, and finally estimating the distance from this exit point to the centroid of the destination S.A. In the case
of the 1964 MTAITS data, the same distance data were used since the road system had not changed significantly over the period.

4. STRUCTURAL FORMS AND DATA BASES

Mixed logarithmic exponential models of the following forms were found to be quite satisfactory in this study:

\[ \ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 X_3 + \beta_3 \ln X_4 + \beta_4 X_5 \cdot \quad (4) \]

and

\[ \ln Y = \beta_0 + \beta_1 \ln X_2 + \beta_2 X_3 + \beta_3 \ln X_4 + \beta_4 X_5 \cdot \quad (5) \]

These equations can be rewritten to show their similarity to the generalized gravity model. Using (4) as an example,

\[ Y = Y_0 X_1^{\beta_1} X_3^{\beta_2} e^{\beta_3 X_4} e^{\beta_4 X_5} \quad \text{where} \quad Y_0 = e^{\beta_0} \quad (6) \]

The major additions to (1) in (6) are the exponential terms in \( X_3 \) and \( X_5 \). These latter two variables have to be entered exponentially because they so, on occasion, assume zero values.

We used a version of (4), omitting \( X_5 \) of course, in which all variables are linear rather than logarithmic. The main problem encountered by him involved a non-linear effect of distance (\( X_1 \) here) on \( Y \). He found substantially improved results using a model similar to the following

\[ Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 \cdot \quad (7) \]
Our own work suggests as well that (7) is a significant empirical improvement on an equation without $\sqrt{X_1}$. In the present work, however, substantial multi-collinearity is evident among $X_1$, $X_3$, and $X_4$ when using (7). This collinearity makes it difficult to interpret estimates of $\beta_3$ in (7) and appears to arise because of wide variations in the values of these variables. The use of logarithmic transformations in (4) and (5) thus substantially reduces the level of multicollinearity and makes the interpretation of $\beta_3$ there somewhat easier. For this reason, (4) and (5) are used in preference to (7).

Models (4) and (5) are estimated using two sets of flow data from each of 1964 and 1971. These two sets are the fringe-to-Metro flows and the fringe-to-anywhere flows. Although it is the first set in which we are most interested, it is helpful to know how similar (or different) are fringe commuting patterns to Metropolitan Toronto from similar flows to other fringe areas. These data sets in 1971 correspond to the 54 x 4 flows and the 54 x 56 flows respectively. In 1964, the corresponding sets are the 35 x 4 and 35 x 39 flows.

The use of a logarithmic commuting flow variable in a model such as (4) necessitates the deletion of all zero commuting flow values. Thus in the 54 x 4 flow data set, for instance, there are 216 possible flows but only 163 are non-zero. The number of non-zero flows in the other sets are indicated in Table 1.
TABLE 1. Sample Sizes in Commuting Flow Data Sets.

<table>
<thead>
<tr>
<th>Year</th>
<th>Description</th>
<th>Destination</th>
<th>Sample Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1971</td>
<td>Fringe-to-Metro</td>
<td>54 x 4</td>
<td>187</td>
</tr>
<tr>
<td></td>
<td>Fringe-to-Anywhere</td>
<td>54 x 58</td>
<td>811</td>
</tr>
<tr>
<td>1964</td>
<td>Fringe-to-Metro</td>
<td>35 x 6</td>
<td>35</td>
</tr>
<tr>
<td></td>
<td>Fringe-to-Anywhere</td>
<td>35 x 39</td>
<td>258</td>
</tr>
</tbody>
</table>

SOURCE: See text

5. EMPIRICAL FINDINGS AND INTERPRETATION: 1971 COMMUTING FLOWS

Using the 54 x 58 (Fringe-to-Anywhere) data set for 1971, the following estimations of (4) and (5) are obtained. 6

\[
\ln Y = 4.602 - 1.651 \ln X_1 + 0.144 X_2 + 0.512 \ln X_3 \\
(\text{L.S.E.}) = (0.287) \quad (32.616) \quad (0.844) \\
R^2 = 0.732 \quad \hat{\beta}_2 = 0.253 \quad F(4,806) = 549.70
\]

\[
\ln Y = 1.009 - 0.589 \ln X_1 + 0.119 X_2 + 0.410 \ln X_3 \\
(\text{L.S.E.}) = (6.635) \quad (34.196) \\
R^2 = 0.720 \quad \hat{\beta}_2 = 0.952 \quad F(4,806) = 519.74
\]

6The values in parentheses below slope coefficients are t-values.
Several comments can be made about these estimates. All coefficients have the signs expected of them. Distance and intervening opportunities (X1 and X2) have negative coefficients while in-migration (X3), the availability of jobs at the destination (X4), and the Go-rail dummy (X5) have positive coefficients. Further, all coefficients are statistically significant (at the 95% level) with the exception of the Go-rail variable. Also in a result which appears recurrently in this statistical work, there is almost no difference between distance (X1) and intervening opportunities (X2) in terms of goodness of fit.

Some slightly altered versions of (4) provide additional information about the estimated relationship (8). Using the same 811 observation data set,

\[
\ln Y = 4.950 - 1.727 \ln X_1 + 0.580 \ln X_4 + 0.454 X_5 \quad (10)
\]

\[
R^2 = 0.709 \quad \hat{\sigma}_u = 0.071 \quad F(3,807) = 655.108
\]

\[
\ln Y = 4.608 - 1.652 \ln X_1 + 0.146 X_4 + 0.512 \ln X_5 \quad (11)
\]

\[
R^2 = 0.732 \quad \hat{\sigma}_u = 0.093 \quad F(3,807) = 732.95
\]

7 The failure of the Go-rail variable can be explained in at least two ways. First, since the Go-rail system had been introduced only a short time before 1971, it may have been too early for the system to have had an effect on overall commuting patterns. On the other hand, Go-rail may have served simply to alter the mode of travel of commuters but not affected the overall volume of commuting.
Examining (11) first, it is seen that the exclusion of the GO-
rail dummy in (8) does not affect the remaining slope
coefficients or the overall goodness of fit. From (10), it
is seen however that the exclusion of the in-migration vari-
able in (8) does lower the $R^2$. On the other hand, exclusion
of $X_3$ does not severely affect any of the remaining slope
coefficients indicating that multicollinearity is not a
serious problem here.

Now do these results change if we exclude the fringe-
to-fringe commuting flows and focus on fringe flows into Metró-
politano Toronto? Using the 183 observation data base, the
following results are obtained comparable to (8) and (10).

$$\ln Y = 4.295 - 1.352 \ln X_1 + 0.159 X_3 + 0.284 \ln X_4$$

(-9.022) (9.476) (5.740)

+ 0.184 $X_5$

(1.072)

(12)

$$R^2 = 0.624 \quad \sigma_n = 0.721 \quad F(4,178) = 73.715$$

$$\ln Y = 5.559 - 1.637 \ln X_1 + 0.215 \ln X_4 + 0.470 X_5$$

(-10.662) (9.774) (2.281)

(13)

$$R^2 = 0.474 \quad \sigma_n = 0.882 \quad F(3,179) = 45.689$$

Estimation (12) is very similar to (8) with respect to
coefficients and t-values except perhaps for the jobs vari-
able ($X_4$). The overall goodness of fit falls somewhat
and this suggests that model (4) fits fringe-to-fringe flows
somewhat better than it does flows into Metro Toronto
although (12) is certainly not a poor "fit". When the
in-migration variable is deleted in this case, the changes
in slope coefficients and t-values is more pronounced.
Comparing (12) and (13), it is seen that deleting $x_3$ alters all the coefficient values and, in the case of $x_5$, makes its coefficient significant. However, the reduction in $R^2$ from (12) to (13) suggests that whatever collinearity may be present between $x_3$ and the remaining independent variables, in-migration still has a large and unique role in explaining the statistical behaviour of commuting.

6. EMPIRICAL FINDINGS AND INTERPRETATION: 1964 COMMUTING FLOWS

While keeping in mind the differences in data used, can a comparison be drawn between the 1964 MTARTS commuting flows and the 1971 Census flows? Using the 258 observations (based on non-zero flows in the $35 \times 39$ commuting matrix) MTARTS data set, the following estimations of (4) and (5) are obtained.

$$\ln Y = 3.197 - 0.923 \ln x_2 + 0.102 x_3 + 0.416 \ln x_5$$ (14)

$(-8.975)$

$$R^2 = 0.606$$

$$\sigma_u = 0.858$$

$$F(3,254) = 127.123$$

$$\ln Y = 1.103 - 0.303 \ln x_2 + 0.112 x_3 + 0.436 \ln x_4$$ (15)

$$(-7.653)$$

$$R^2 = 0.572$$

$$\sigma_u = 0.887$$

$$F(3,254) = 113.208$$

Note that the GD-rail dummy has been excluded because the transit system did not exist in 1964. ln terms of statistical fit, all variables have the correct sign and are statistically significant. A comparison with the similar models for 1971, namely (8) and (9), shows that although the overall goodness of fit has increased from 1964 to 1971 there are remarkable
similarities in the estimated slope coefficients of the two models. Since the 1964 commuting data refer only to household heads who generally commute longer distances than other commuters, the only large difference in coefficient values, that between coefficients of distance \((X_3)\), is understandable. In addition, the MORTIS data do not indicate a multi-collinearity problem with respect to the in-migration variable. When \(X_3\) is deleted from (14), for example, there are relatively small changes in the values of the remaining slope coefficients:

\[
\ln Y = 3.897 - 1.120 \ln X_1 + 0.496 \ln X_4 \quad (16)
\]

\[
R^2 = 0.547 \quad \hat{\sigma}_u = 0.311 \quad F(2,255) = 153.995
\]

If one examines the fringe flows into Metropolitan Toronto alone (the 35 x 4 case), the following estimations are obtained comparable to (14) and (16):

\[
\ln Y = 3.611 - 1.284 \ln X_1 + 0.102 X_3 + 0.575 \ln X_4 \quad (17)
\]

\[
(-5.474) \quad (4.530) \quad (8.842)
\]

\[
R^2 = 0.637 \quad \hat{\sigma}_u = 0.821 \quad F(3,91) = 53.324
\]

\[
\ln Y = 5.259 - 1.770 \ln X_1 + 0.681 \ln X_4 \quad (18)
\]

\[
(-7.709) \quad (10.181)
\]

\[
R^2 = 0.556 \quad \hat{\sigma}_u = 0.903 \quad F(2,92) = 57.522.
\]

These two equations have slope coefficients which are quite similar to those in (14) and (16). Again from these results, the statistical significance and unique contribution of the residential relocation variable is seen.
7. EMPIRICAL FINDINGS AND INTERPRETATION: COMBINED 1964 AND 1971 DATA SET

The findings just described lend some support to the notion that residential relocation has a significant effect on commuting patterns. One question which might be raised, however, concerns the extent to which our variable X1 is accurately singling out the specific role of recent residential relocation. It might be argued that, given consistent spatial patterns of residential relocation over time, the variable X1 is serving as a proxy for a number of unstated variables which have traditionally linked Statistical Areas "i" and "j". This is a difficult criticism to surmount without more specific ideas about the process involved.

It is possible, however, to begin to separate the effects of relocation at different points in time on current commuting behaviour. Does the relocation of a household ten years ago have the same effect on current commuting patterns as a similar move by a household last year? Given the predominance of fringe-bound residential relocation and given no relative change in the spatial pattern of jobs, the answer might be no. However, given that jobs too are decentralizing, the answer is more likely to be yes. If a residence moves for non-commuting reasons and in so doing creates for itself a longer journey-to-work, one might expect over time that either the firm will move somewhat closer to the residence or else the worker will tend to seek out a new employer at a reduced distance (or improved travel time).
Some evidence of this phenomenon can be found. Using the 1971 54 x 4 data set reduced to a 35 x 4 set to make it comparable to the 1964 data, it is possible to re-estimate models such as (12) using two residential relocation variables.

$$\ln Y = 3.924 - 1.269 \ln X_1 + 0.146 X_{55-64}^9 + 0.008 X_{55-64}^{9-10}$$

$$(-6.837) \quad (7.132) \quad (3.521)$$

$$+ 0.275 \ln X_6 + 0.037 X_5$$

$$R^2 = 0.685 \quad \sigma = 0.723 \quad F(5,126) = 55.407$$

All variables in (19) except $X_{55-64}^{9-10}$ are the same as in model (12). The new variable, $X_{55-64}^9$, is the $X_3$ variable taken from (17). These variables are only approximately comparable since $X_{55-64}^{9-10}$ refers to movements of household heads while $Y$, $X_{55-64}^9$, and $X_5$ refer to the entire population.

By comparing (12) and (19), some interesting observations follow. First, the coefficient of $X_{55-64}^9$ is only one-half the size of the $X_{55-64}^9$ coefficient implying that relocation in more remote periods does have a smaller (though still significant) effect on current commuting.

Secondly, it is also seen that the introduction of $X_{55-64}^{9-10}$ does not significantly affect any of the other coefficient values. This indicates that the contribution of more remote relocation movements had not been captured in the earlier model (12). This seems to refute in part the argument that $X_{55-64}^9$ is just a proxy for a number of variables which have traditionally linked areas "1" and "3".

Why is there no substantial collinearity between $X_{55-64}^9$ and $X_{55-64}^{9-10}$? The answer seems to lie in the shifting position of the fringe. In the 1959-1964 period, the predominant patterns of relocation were to the three boroughs.
(Etobicoke, North York, Scarborough) with relatively smaller amounts to further outlying areas. By the 1966-1971 period, these boroughs were approaching development saturation and the predominant flows of relocation had shifted to the next tier of Statistical Areas such as Mississauga, Vaughan, Richmond Hill, Markham and Pickering. This, one finds a relatively small correlation between 1959-1964 and 1966-1971 relocation flows.

8. CONCLUSIONS

Several conclusions can be drawn from this empirical work. First, whether we examine just fringe commuting flows into Metropolitan Toronto or all fringe commuting flows to other Statistical Areas, recent residential relocation from area "i" to area "j" has a significant effect on the level of commuting from "j" back to "i". Further, this is an effect which, in terms of the explanatory variables used, is unique. That is to say that multicollinearity among the independent variables does not appear to be a significant problem. Thirdly, this effect appears to be remarkably constant over time (at least from 1964 to 1971) in terms of a stable regression coefficient. Fourthly, if residential relocation variables are considered covering two previous periods, the more remote period seems to have a unique, if smaller, numerical significance in explaining current commuting flows. Finally, these results appear to be independent of the choice of distance-effect variable; distance or intervening opportunities.

This study provides an initial, crude piece of evidence that traditional trip distribution models such as (1)
although widely used in transportation planning, can be significantly improved upon by the inclusion of variables describing the residential relocation process. This study suggests it is unwise to ignore residential relocation in predicting journey-to-work flows.

9. BIBLIOGRAPHY


