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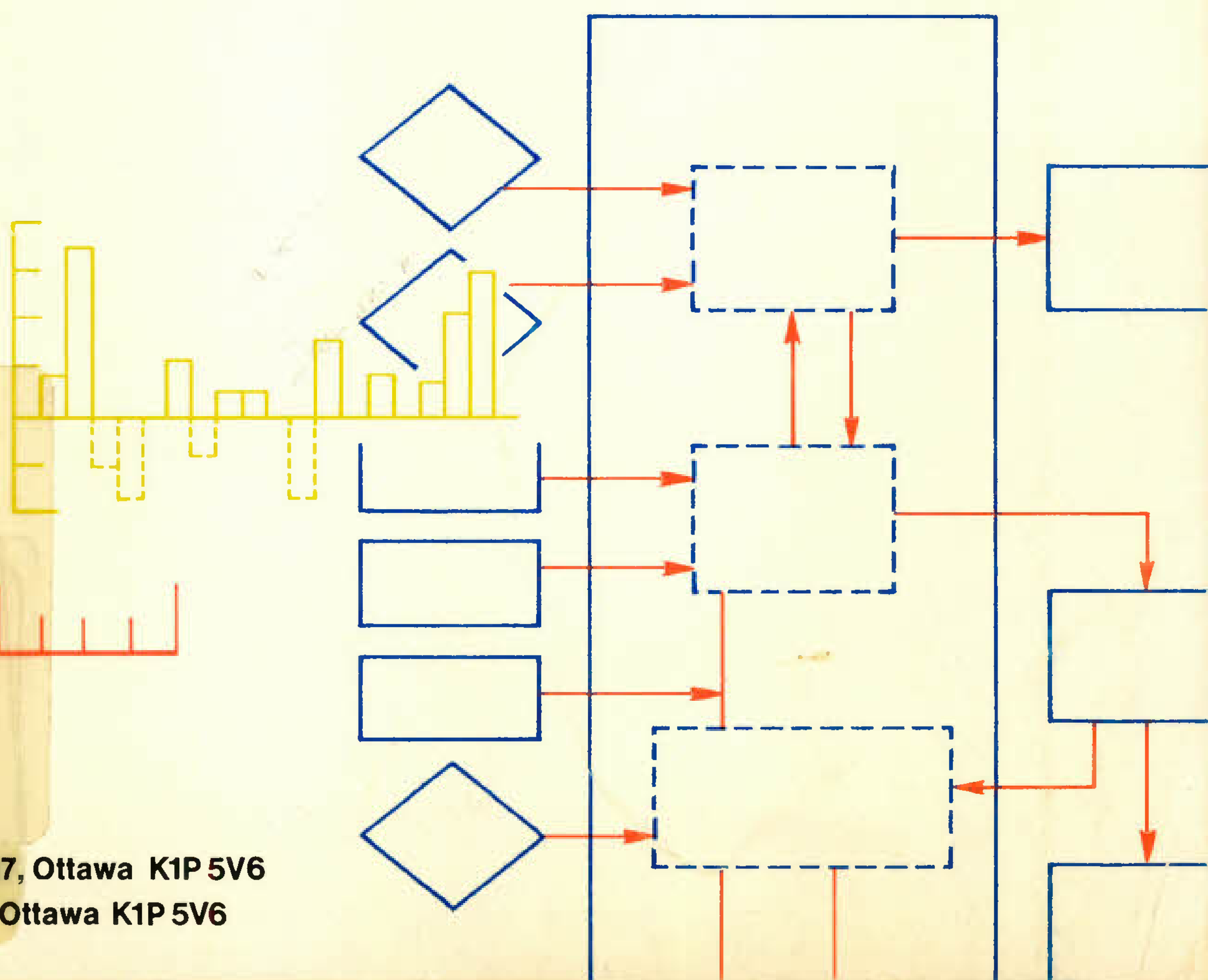

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DISCUSSION PAPER NO. 124

An Econometric Analysis of Residential and Job Location Behaviour in a Metropolitan Area

Urban Paper No. 5

by
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ABSTRACT

In this paper we present and estimate two single equation models designed to explain respectively the residential location and job location behaviour of individuals living in a multi-centered metropolitan area. We test both models separately for heads of households and non-heads of households, as well as for the total working population, in order to isolate differences in commuting behaviour between primary and secondary wage earners. The relationships are estimated from 1971 Census, cross-section data using least squares multiple regression. The data pertain to the Toronto Census Metropolitan Area (CMA) and sixty-three designated zones therein.

The 'residential location model' assumes a fixed job site and attempts to explain the individual's choice of residential location. The estimation results reveal that urban structure variables are the most important determinants of the journey-to-work distance in this model. Although location-rents prove to be significant in the individual's residential location decision-making process, their effect was limited to discouraging those employed in or near the central business district (CBD) from living close to work. The existence of secondary employment centres did not have the same significant effect in bidding up location-rents. Furthermore, contrary to the standard theory, the results suggest that residential location decisions are made in response to the availability of collective residential opportunities and workers' preferences for specific residential attributes rather than by reference to the "transportation cost - housing cost" trade-off. Among the socio-economic variables, age of the worker is found to be most significant in affecting journey-to-work distance. The results provide some evidence that non-heads are, to a certain extent, more sensitive to urban structural constraints in their commuting behaviour.

The 'job location model' assumes a fixed residential location and seeks to establish the variables which influence the individual's choice of job site. Here the estimation results indicate that structural variables are important determinants of job location and that, for heads of households, the wage gradient is also important. On the other hand, non-heads are rather insensitive to the wage gradient. Rather, contrary to the decisions of heads, the job-location choices of non-heads are strongly influenced by socio-economic attributes, notably occupation, family size and age. Clearly, job location decisions of primary wage earners (usually the household heads) are influenced by earnings-maximizing considerations while secondary earners (non-heads in general) put more weight on other factors.

Both models are helpful in explaining commuting behaviour; however, the results imply that the models are most relevant to decisions taken by household heads. The results of the testing of the models suggest that there is a hidden cost associated with uneven directional growth in the Toronto CMA. The results also suggest that urban planning strategies should reflect consideration of the greater desire or need for accessibility on the part of secondary wage earners (non-heads) and the need to balance residential and job opportunities at the extending margin of the urban area.

RÉSUMÉ

Dans ce document, nous présentons et estimons deux modèles à une équation destinés à expliquer les raisons du choix d'un lieu de résidence et d'un lieu d'emploi par les personnes qui vivent dans une zone métropolitaine à plusieurs centres d'affaires. Nous testons les deux modèles séparément dans le cas des chefs de ménage et des non-chefs de ménages, ainsi que pour l'ensemble des travailleurs, afin d'isoler les différences entre les schèmes de déplacement des premiers et des seconds gagne-pain. Les estimations des relations fonctionnelles se fondent sur des coupes instantanées du recensement de 1971, et nous avons employé la régression multiple par la méthode des moindres carrés. Les données portent sur la région métropolitaine de recensement de Toronto ainsi que sur 63 zones désignées à l'intérieur de cette région.

Le "modèle sur le lieu de résidence" suppose que le lieu d'emploi est fixe et tente d'expliquer le choix d'un lieu de résidence. Les résultats des estimations montrent que, dans ce modèle, les variables relatives à la structure urbaine sont les principaux déterminants de la distance à parcourir pour aller au travail. Bien que l'endroit et le loyer jouent un rôle important dans la décision d'une personne de se choisir un lieu de résidence, ils n'ont eu d'autre effet que de décourager les personnes travaillant dans le centre des affaires de vivre à proximité. L'existence de centres de travail secondaires n'a pas eu le même effet sensible sur la hausse des loyers. En outre, contrairement à la théorie couramment admise, les résultats obtenus montrent que les décisions relatives au lieu de résidence sont influencées par l'existence de possibilités collectives en cette matière, et par les préférences des travailleurs pour une foule de facteurs spécifiques d'ordre résidentiel, plutôt que par référence à l'arbitrage "coût du transport-coût du logement". La variable socio-économique la plus importante dans le cas de la distance pour aller au travail est l'âge du travailleur. Les résultats indiquent aussi dans une certaine mesure que les non-chefs de ménage sont, jusqu'à un certain point, plus sensibles aux contraintes de la structure urbaine dans leur comportement de banlieusards.

De son côté, le "modèle relatif au lieu d'emploi" suppose un lieu de résidence fixe et cherche à établir les variables qui influent sur le choix d'un lieu d'emploi. Les résultats des estimations indiquent ici que les variables structurelles sont d'importants déterminants du choix d'un lieu d'emploi et que, pour les chefs de ménage, le

"gradient" de salaire est aussi important. D'autre part, les salariés non chefs de ménage sont plutôt insensibles au "gradient" de salaire. En fait, contrairement aux décisions des chefs de ménage, le choix d'un lieu d'emploi par les non-chefs de ménage est fortement influencé par des facteurs socio-économiques, notamment la profession, la taille de la famille et l'âge. Somme toute, ce qui influe sur les décisions des premiers gagne-pain (habituellement les chefs de ménage) ce sont des considérations de maximisation du revenu, tandis que pour les seconds (qui ne sont pas en général chefs de ménage), ce sont plutôt d'autres motifs.

Les deux modèles sont utiles pour expliquer les schèmes de déplacement. Cependant, si l'on en juge par leurs résultats, ils s'appliquent mieux aux décisions des chefs de ménage. Les tests des modèles montrent qu'il existe un coût caché découlant d'une croissance directionnelle inégale de la région métropolitaine de recensement de Toronto. Ils indiquent également que les stratégies de planification urbaine devraient tenir compte du désir ou du besoin plus grand d'accessibilité de la part des seconds gagne-pain (ceux qui ne sont pas chefs de ménage) ainsi que de la nécessité d'équilibrer les possibilités d'emploi et de résidence à la périphérie sans cesse plus étendue de la région urbaine.

ACKNOWLEDGEMENTS

The authors would wish to express their appreciation for the valuable contribution to this paper of D.W. Henderson and D. Paproski. We are also thankful to G. Betcherman for his cooperation throughout this study; S. Rao and T. Hazledine for their advice on model estimation; J. Laperrière and H.W. Wiggeshoff, for performing the computer operations, and to Jocelyne Parisien and Rita Sunstrum for typing the text. The authors, however, are responsible for any errors or remaining shortcomings in the analysis.

Introduction

In an earlier paper,[1] we proposed an outline of the basic structure of two models. The purpose of these models is to examine the residential location and job location behaviour of the working population within a multi-centre metropolitan area, when the polycentric nature of workplace locations is taken into account during the locational process. One of these, the "Residential Location Model", assumes a given job site and allows for a choice of the residence site, while the "Job Location Model" assumes a given residence site and allows for a choice of job location.[2] While both models are viewed as alternative explanations of the same phenomenon, i.e., the commuting behaviour of workers as reflected in journey-to-work distance, it should be stressed that these models are complementary and not competing accounts, since they imply quite different decision frameworks.[3]

The purpose of this paper is to empirically test the proposed models, using data on the commuting behaviour of workers in the Toronto Census Metropolitan Area (CMA). To highlight the differential applicability of the two models,

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1 Gera and Kuhn (1977).

2 As argued elsewhere, *ibid*, pp. 50-51, we do not model the job and residence location decisions as simultaneous. A simultaneous model is more appropriate for studies relating to inter-metropolitan migration (e.g. in some cases of structural unemployment with heavy local dependence on one industry, forcing a move of residence to another town).

3 We are thankful to Prof. M.E. Beesley of the London Graduate School of Business Studies and Peter Kettle of Nathaniel Lichfield & Partners, London, U.K., for suggesting this point in their comments and suggestions on our earlier paper (cited in footnote 1).

both models are also separately estimated for two subpopulations: heads of households, and non-heads of households.[4] Of course the process of model testing requires more detailed consideration of the problems of data availability, variable selection, and model requirements. Thus, the specification of the models proposed and tested in this paper, while drawn from the theoretical structure proposed in our earlier paper, differs somewhat in form from those outlined earlier.

The study begins with a recapitulation of the theoretical consideration underlying the structure of the residential and job location models followed by a description of the data used. Then, the model operationalization and specification are discussed and estimation results for both models are analyzed separately for heads and non-heads of the households. In conclusion, the implications of the results both for the validity and usefulness of the underlying theory, and for urban policy and planning, are discussed.

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4 See the definition on p. 13. Indeed, most of the journey-to-work theory and research to date have been based on the behaviour of primary wage earners (heads of households) in the family. Our attempt to separately deal with secondary wage earners (non-heads of households) is among the first efforts of this kind. Since secondary wage earners make up a very large and growing proportion of the commuting population in Toronto CMA, as in all Canadian urban areas, an understanding of the determinants of their journey-to-work behaviour is essential.

Section 1: Theoretical Considerations and the Structure of the Models

1.1 The Residential Location Model

The economic model presented in this sub-section is adopted from the studies of Alonso (1964) and Muth (1969) and is based on a theory of residential location. In the traditional theory of residential location, which is based on a simple monocentric concept of the city, it is assumed that all the jobs are located in the urban centre, so that the household chooses its location site in relation to the exogenously given job site in the central business district (CBD). The theory assumes that in a competitive housing market, the bidding process by various households has established a negatively sloped location rent gradient as one moves away from the city centre, implying that housing prices or rents decline (at first rapidly and then flattening toward the periphery) with increasing distance from the CBD job site while transportation costs increase (assuming that transportation costs are a monotonically increasing function of distance from the CBD regardless of the direction of travel). A trade-off occurs between housing expenditures and transportation costs as the households attempt to maximize the utility of their income.[5]

In the model posited, we examine the residential location behaviour of the individuals within a multi-centre

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5 For a literature review of the conventional residential location model and recent developments in theory and our proposed theoretical structure of this model, see Gera and Kuhn (1977).

metropolitan area. The polycentric nature of workplace locations, rather than the CBD alone, is taken into account during the locational process. Similar to a standard residential locational model, we assume that an individual's utility is a function of housing consumption q, a composite good z, and commuting activity D. Thus, an individual's utility function is expressed as follows:

$$u = U(z,q,D) \qquad (1)$$

We assume that the consumption of housing is a function of a vector of housing attributes, H, including, for example, type of dwelling and number of bedrooms. Thus,

$$q = q(H) \qquad (2)$$

Then, an individual's utility function can be specified as follows:

$$u = U[z,q(H),D] \qquad (3)$$

It is further assumed that the price per unit of housing consumption, R, is related to the distance of the residence from the workplace; specifically, that $R = R(D)$ and $\frac{\partial R}{\partial D} \leq 0$. Also, transportation costs (T) are assumed to be a positive function of income (Y) and a monotonically increasing function of distance (D). This allows us to express the individual's budget constraint as follows:

$$Y = p\cdot z + R(D)\cdot q(H) + T(D,Y) \qquad (4)$$

where p is the price of the composite commodity z. In order to maximize the utility function (3) subject to the budget constraint (4), an individual's Lagrangian function can be expressed as

$$L = U[z,q(H),D] + \lambda[Y - R(D)\cdot q(H) - T(D,Y) - p\cdot z] \quad (5)$$

Maximization of utility subject to the budget constraint yields the following conditions:

$$\lambda = \frac{U_z}{p} = \frac{U_{q(H)}}{R(D)} = \frac{U_D}{R_D(D)\cdot q(H) + T_D(D,Y)} \quad (6)$$

where the subscripts indicate partial derivatives and λ can be interpreted as the marginal utility of income. The denominators in (6) can be interpreted as the "prices" of the three goods in question. In the operational form of the residential location model we focus particularly on the "price" of distance, which consists of three components: the first, $R_D(D)$, gives the rate of decrease of location-rents with distance from the workplace -- the location-rent gradient. The second, q(H) is housing consumption,[6] so that $R_D(D)\cdot q(H)$ represents the marginal savings in total housing expenditure available to the worker by moving farther from the job site. Finally, $T_D(D,Y)$ represents marginal transportation costs.

Based on these considerations, we propose that, for purposes of estimation, the main factors determining home-work distance, D, in the residential location model are the three components of the "price" of distance[7] -- the location-rent

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6 In a theoretical sense, q is endogenous to the model and is determined by preferences, income, family size, etc., we refer to this concept of housing consumption as "housing space demands" in the ensuing analyses.

7 The cross-sectional variation in the price of the composite commodity (z) is assumed to be not significant enough to have any effect on commuting distance.

gradient, housing space demands, and marginal transportation costs -- income and a set of socio-economic factors (SE)[8] that may have an effect on the location decision. Equation (7) below describes the structural form of the model to be estimated.

$$D = f(R_D(D), q(H), T_D(D,Y), Y, SE) \tag{7}$$

The standard implications for residential location behaviour of an individual, obtained from the above model, may be summarized as follows:

(i) An individual locates at a distance from the workplace such that a small change in distance brings a change in marginal housing expenditures which is equal but opposite in sign to the change in marginal transportation costs around the optimum location.

(ii) Any increase in the individual's consumption of housing (due to increase in family income and/or increase in family size or other social factors) would require it to locate further from the workplace in order to remain at the optimal location. However, the effect of an increase in the family income upon equilibrium distance is ambiguous because of the two consequent forces working in opposite directions. The increase in the consumption of housing induces an outward move and the marginal value of time induces an inward move. The net effect would also depend upon the elasticity of the individual's marginal utility function with respect to housing.[9]

The empirical model of residential location, then, is formulated from the structural relationship defined by

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8 The observed socio-economic characteristics that affect an individual's utility are not generally specified in the utility function; however, if we explicitly incorporate them, equation (3) can be rewritten as

$$u = U(z, q(H), D, SE) \tag{3}$$

See for example, McCarthy (1977).

9 See, Gera and Kuhn (1977), pp. 26-28.

equation (7). The model operationalization and estimation procedure is discussed in Section 3.

1.2 The Job Location Model

The theoretical model of job location was developed by Beesley and Dalvi (1974), who proposed that for some members of the urban population, particularly secondary wage earners in the family, variations in commuting distance may be best explained as rational economic decisions on where to work, given a predetermined residence site.[10] It is assumed here that there is one, city wide market for labour of all types, that transportation costs are a monotonically increasing function of distance in all directions, and that the costs of moving one's residence are sufficiently high to make the theory workable.

Under our assumptions, we consider workers who are making a decision about job location in any one of the j zones in the metropolitan area, so as to maximize their net earnings. Following Beesley and Dalvi, let W_i be the worker's earnings from employment in the home zone i (net of search costs), and W_j be the earnings from employment at a more distant location j (again, net of search costs). Assuming a positive relationship between earnings and distance,[11] let

$$WL = W_j - W_i \geq 0 \tag{8}$$

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10 For detailed discussion of Beesley and Dalvi's (1974) model, the list of assumptions and our proposed theoretical structure of the model, see *ibid*, pp. 50-57, and 80-91.

11 However, earnings are bounded from above, in the sense that there is an upper limit upon the amount of earnings one may earn by taking up jobs farther away from the residence site.

where WL is the potential earnings differential between employment sites i and j. We assume that WL is an increasing function of journey-to-work distance (D) but that it increases at a diminishing rate with D. Thus,

$$WL = WL(D) \tag{9}$$

Then, the individual's earnings (net of search costs) at any location j may be expressed as,

$$W_j = W_i + WL(D) \tag{10}$$

and W_n is defined as earnings (net of search costs) less commuting costs. Thus,

$$W_n = W_j - T(D) \tag{11}$$

where T(D) is the transportation costs, or

$$W_n = W_i + WL(D) - T(D) \tag{12}$$

Differentiating equation (11) with respect to D and setting the derivative equal to zero, we obtain

$$WL_D(D) - T_D(D) = 0$$

or

$$WL_D(D) = T_D(D) \tag{13}$$

where subscripts represent partial derivatives. The above condition (13) indicates that for the individual's utility to be at a maximum, the worker will attempt to find a job at a distance from his (her) residence site where the marginal increase in his (her) earnings is equal to the marginal increase in his (her) commuting costs.

Conceptually, then, it appears that the optimum home-work distance, D, in this model is a function of two main factors -- the rate of increase of earnings with distance from the residence site, $WL_D(D)$, or the "wage gradient", and marginal transportation costs, $T_D(D)$. If we further propose that a set of socio-economic and demographic factors (SE) may also have an effect on the optimum commuting distance, perhaps by affecting the utility of earnings, the structural form of the model to be estimated can be described as,

$$D = f(WL_D(D), T_D(D), SE) \quad (14)$$

The standard implication for the job location behaviour of an individual, obtained from the above model, may be summarized as follows:

(i) An individual locates his job at a distance from the residence site so as to maximize his earnings, net of transportation and job search costs, by trading off possible increases in earnings at more distant job sites against marginal increases in commuting costs.

In Section 3, we consider the variables that fall under the three main categories -- the "wage gradient", transportation costs, and various socio-economic and demographic factors -- and we discuss their operationalization in this model.

Section 2: The Data

From the responses to the 1971 *Census of Population and Housing*, it is possible to ascertain the residential location of the employed labour force of Canada, as of June 1, 1971. In addition, the 1971 Census collected job location information on a national basis for the first time. From these responses, journey-to-work data, consisting of the place of residence and place of employment, was coded for one-ninth of the complete population. Full population estimates were made by Statistics Canada from this sample. This study uses Statistics Canada's place-of-residence and place-of-work data for the Toronto Census Metropolitan Area (CMA). Although data for the Toronto CMA were available on a census tract (CT) level, the 453 CTs in the CMA were aggregated into 63 zones.[12] For each of these zones in the Toronto CMA, information was available on the resident labour force (L_i) in the zone of residence; the working labour force (E_j)[13] in the zone of work; and the flow of commuters (a_{ij})[14] and commuting distances (d_{ij})[15] between

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12 For the definition of the various terms used here (for example, CMA, CT), and a description of the criteria used for aggregation, see S. Gera, G. Betcherman, and D. Paproski (1978).

13 The 'resident labour force' (L_i) of a zone includes all employed residents living in that zone whose place of work is known and within the CMA. The 'working labour force' (E_j) of a zone includes all those whose jobs are located in that zone, residing in the CMA or within a fifty-mile radius.

14 The commuting flow (a_{ij}) between any pair of zones is defined as the number of workers who live in zone i and work in zone j.

15 The commuting distance (d_{ij}) is the airline-mile distance between any pair of zones i and j. We found that a high zero-order correlation (r = .91) existed between airline-mile distance and road-mile distance suggesting that airline-mile distance might be regarded as a reasonable proxy for actual distance commuted.

any pair of zones. Further, these data were disaggregated by socio-economic attributes such as occupation, sex, age and family size, etc. for this study.

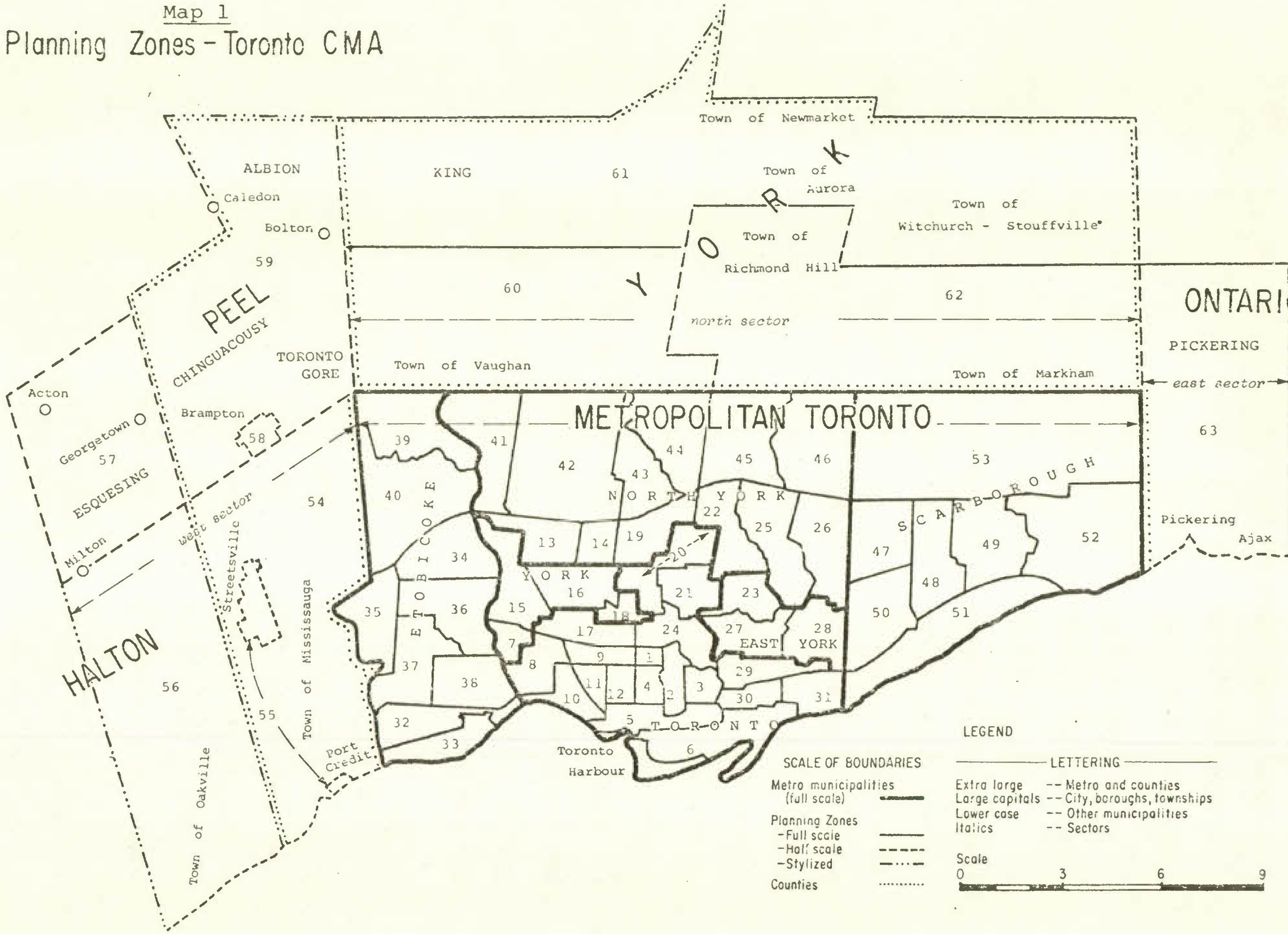
Both models are tested in terms of the "average" characteristics of the workers on a zonally aggregated basis.[16] All of the 63 zones in the Toronto CMA (See Map 1) were assumed to be places of residence and places of work, so that two distinct data sets -- one based on the average characteristics of the resident labour force (L_i) of each zone and the other based on the average characteristics of the working population (E_j) of each zone -- could be constructed. In other words, the aggregate data are arranged separately for journeys originating or terminating in a given zone. It should be mentioned that the number of observations for each of the variables used in the model was equal to the number of zones in the CMA but that the average zonal value for each of the variables was calculated from individual observations ranging in number up to several thousands.

The residential location model, which attempts to explain the variation in the work-trip length of individuals given a fixed job location, uses the second of the "data sets" described above. Thus, the dependent variable in this model is the average commuting distance (D_j) of all those employed in zone j (where j = 1.....63). Conversely, the job location model, which assumes a fixed residence site, uses the first of

16 Ideally we would have liked to test the models in terms of the 'individual' characteristics of the workers as mentioned in Gera and Kuhn (1977), p. 67 but could not do so due to data problems.

Map 1

Planning Zones - Toronto CMA



the above data sets, attempting therefore to explain the variation in the average commuting distance (D_i) of all those resident in zone i (where i = 1.....63).

We test both models separately for heads of households[17] and non-heads of households and for the total sample in order to isolate the differences in commuting behaviour between primary and secondary wage earners.[18] We realize, of course, that the Census classification of the sample into heads and non-heads of households is only a rough approximation of the concepts of primary and secondary wage earners, and may be becoming obsolete due to changing social norms.[19] Still, given the prevailing form of family structure in 1971 (and indeed today) it is the best approximation available from our data set and should give an adequate picture of the differences in commuting behaviour between primary and secondary wage earners. Indeed, inspection of the data on the dependent variables in the models shows that the 545,520 household heads in the Toronto CMA travelled an average of 5.7 miles to work in 1971, while the 457,665 non-heads had an average distance of

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17 The 1971 Census defined 'Household Head' as follows -- "For census purposes, every Household must have a Head. This is the husband if both husband and wife are present, the parent (regardless of age or dependency) if living with unmarried children, or any member of a group sharing a dwelling equally". For further remarks, see Statistics Canada, *Dictionary of the 1971 Census Terms*, Catalogue 12-540, 1972, p. 11.

18 See the rationale and discussion on p. 15.

19 Indeed, Statistics Canada seems to have recognized this in changing its definition of "household head" in the 1976 Census. See 1976 Census of Canada, Statistics Canada, Bulletin 3.11, Household and Family Status of Individuals, Catalogue 93-810, p. vi.

only 4.1 miles. Thus, important differences in commuting behaviour seem to exist between the two groups; one of the main aims of testing the models here will be to highlight the reasons for these divergent observations.

Section 3: Model Operationalization and Estimation Procedure

As discussed earlier, both models attempt to explain the distance of journey-to-work. In the residential location model, individuals make a choice of residential location from a given employment site while in the job location model, job location choice is made from a given residence site. Our hypothesis here is that the two models are perhaps differentially applicable to various subpopulations. The residential location model may be more applicable to primary than secondary earners. If we define a primary wage earner as the worker whose earnings provide the main source of support for his (her) family, one might expect the entire family's residence location decision to be made with respect to the primary earner's job site. Thus, we hypothesize that it is the job site of the head of the household (primary earner) that influences the residential location decision, the employment site of other household members (secondary earners) being on a more or less opportunistic basis. The job location model is particularly pertinent with respect to non-heads of the household (secondary earners), who will be more likely to seek work from a given residential location. The ensuing empirical testing will attempt to ascertain whether these hypothesized differences in journey-to-work behaviour do in fact exist.

In both models, the set of independent variables can be said to fall into two categories. The first category, the "urban structure" variables, includes the rent gradient in the residential location model, measuring the price and availability of housing opportunities at or near the worker's (given) job site. In the job location model, on the other hand, this category of variables includes the wage gradient, here measuring the relative wage level and availability of jobs near the worker's (given) residence site. The second category of variables in both models concerns the socio-economic characteristics of the workers. Some of these have specific interpretations in light of the theories, such as transportation costs and housing demand; others have more complex interpretations which are described in turn. The determination of the relative influence of the two classes of variables we distinguish here, however, is an important objective of the subsequent model testing.

3.1 Model Operationalization

The first stage in the operationalization of the residential and job location models involves the selection of the explanatory variables under the two categories discussed above and those selected are entered into the testing of the models. The basis for selection of the explanatory variables is as follows. We recognize that, of the many possible explanatory variables affecting journey-to-work distance in large metropolitan areas, several may often be significant proxies for each other. This is especially true when the data are on a zonally aggregated basis. Our objective, therefore, is to provide the equations in a form in which they have relatively few explanatory variables, among which multicollinearity has been reduced to the greatest possible degree.

The second stage involves a detailed study of the selected explanatory variables with respect to the way in which they should be expressed for use in the testing of the models.

3.1.1 The Residential Location Model

We now define the variables in order to clarify our approach in estimating the equations, when the model is tested in terms of the "average" zonal value for each of the variables.

In general, subscript i refers to the zone in which the residence is located and j to the zone in which the job is located, where i and j = 1, 2, ...63. Now let,

a_{ij} = number of workers commuting from residence in zone i to zone j,

d_{ij} = airline distance between zone i and j,

E_j = total number of workers employed in zone j,

or $$E_j = \sum_{i=1}^{63} a_{ij}.$$

Dependent Variable

With the above notations, the *dependent variable* in the residential location model is defined as follows:

D_j = average distance of journey to work by workers employed in zone j,

$$D_j = \frac{\sum_{i=1}^{63} a_{ij} d_{ij}}{E_j}$$

Independent Variables

Urban Structure Variables

3.1.1(a) Rent Gradient Variables

The role of the rent gradient variables in the residential location model is to measure the level of location-rents at the (given) workplace, *relative* to surrounding areas, thus indicating the extent to which the worker can save in housing expenditures by living farther from the job site. Ideally, this would involve using data on the price per square foot of residential space of a given quality in each of the zones used in the analysis. However, because of the absence of such data and several definitional problems involved in computing such a variable,[20] an alternative approach must be considered.

In this study, we postulate that the *relative* level of location-rents at the workplace will be determined by the *relative* concentration of employment. What this implies is that workers and other firms will offer higher bids in the urban land market in order to locate nearby. Thus, both the central business district and secondary employment centres will tend to create peaks in the location-rent surface; this is reflected in our use of two proxies for the rent-gradient.[21]

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20 This includes selecting a suitable criterion for imputing the value of rent to owner-occupied dwellings and the problem of holding housing "quality" constant when measuring the variation in rents.

21 In addition, other proxies (e.g. a dummy variable indicating whether the workplace is near Lake Ontario or not (see, Gera and Kuhn, 1977, pp. 68-72)) were tested but found to be of no significance in the present model.

-- <u>DC_j (distance between the zone of work j and the CBD):</u>

This variable accounts for the tendency of location-rents to decline at a diminishing rate in all directions from the city centre. Thus, to represent marginal savings in location-rents at the workplace, DC_j enters into the estimating equation in reciprocal form.[22] A positive relationship is expected between the dependent variable (D_j) and the reciprocal of DC_j.

-- <u>ED_j (employment density at the workplace j):</u>

Major centres of employment besides the CBD will tend to cause minor peaks in location-rents, thus causing higher location-rents at secondary employment concentrations relative to surrounding areas. A higher density of employment per acre of land at the workplace implies greater competition for available land both by firms and workers; this means there are greater savings in location-rents to be realized by moving farther away. Thus ED_j is expected to have a positive coefficient. This variable is formulated as follows:

$$ED_j = \frac{E_j}{LA_j}$$

where ED_j = number of jobs per acre of land in zone j, and

LA_j = total land area (in acres) in zone j

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22 See, Gera and Kuhn (1977), p. 43, where it was argued that in order to capture marginal change in location-rents, $(1/DC_j^2)$ might be an effective proxy. Actually, it was found that $(1/DC_j)$ performs better and also represents the non-linear nature of this relationship.

3.1.1(b) Other Urban Structure Variables

-- SI_j (concentration of service industries at the workplace j):

This variable is also related to the shape of the rent gradient, but in a less direct way. On the one hand, service industry concentration may reflect a high degree of competition for land and thus a high level of location-rents in a zone,[23] and on the other, this concentration relates to variations in housing or neighbourhood amenities. If the type of economic activity at the work site is largely of a non-nuisance "service" nature, the worker has an added incentive to live close to the workplace, since pleasant neighbourhood attributes are available to him with minimum cost of commuting. Since the two forces are working in opposite directions, the impact upon journey-to-work distance arising from an increase in the concentration of service industries is ambiguous. The variable is defined as,

SI_j = the percentage of workers in zone j employed in service industries,

$$SI_j = \frac{\sum_{i=1}^{63} SI_{ij}}{E_j} \cdot 100$$

where SI_{ij} = number of workers employed in service industries in zone j commuting from residence zone i.

-- RP_j (residence potential at the workplace j):

This variable indicates the proximity of the job site to residential opportunities and in some sense, relates to the

23 See, Stucker (1975), p. 126.

"search costs" of housing. A greater proximity to residential opportunities should imply low commuting distance, since a greater variety and selection of residential opportunities are available near the place of work.

Residence potential (RP_j) at the zone j is calculated using the formula:[24]

$$RP_j = \sum_{i=1}^{63} \frac{L_i}{d_{ij}}$$

where L_i = total number of workers living in residence zone i.

When calculating the contribution of residential opportunities within a zone itself to its potential at that zone (i.e., when i = j) d_{ij} was set at unity.

Socio-Economic Variables

3.1.1(c) Transportation Cost Variables

Transportation costs are very important in this model. In both direct (money costs) and indirect (money valuation of time) terms, these costs are traded off against potential savings in housing expenditures. In the absence of data on transportation costs, we use the following three proxies.

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24 Theoretically, RP_j should be calculated as follows:

$$RP_j = \sum_{i=1}^{63} \frac{L_i}{{d_{ij}}^{\alpha}}$$

where α is a parameter reflecting distance deterrence. Several trials were made with alternative values of α, it was found that a value of unity was most satisfactory.

-- CO_j (workers in the zone of work j who belong to households owning one or more cars):

If car-ownership is determined mainly by non journey-to-work considerations, it should have a positive effect on commuting distance by lowering the marginal cost of the journey-to-work.[25] It should be mentioned that car-ownership is measured per household rather than per worker in the 1971 data base. The variable is calculated as follows:

CO_j = the percentage of workers employed in zone j belonging to households owning one or more cars,

$$CO_j = \frac{\sum_{i=1}^{63} CO_{ij}}{E_j} \cdot 100$$

where CO_{ij} = the number of workers in households owning one or more cars and commuting from residence zone i to zone j.

-- N_j (workers belonging to families with more than one wage earner):

This variable, which indicates the degree of family labour force participation, accounts for the effect of joint commuting costs on journey-to-work distance. It is expected that the presence of another wage earner in the family will induce workers to travel shorter distances on average to work, since the family will locate in such a way as to reduce total

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25 In consideration of a proposition argued elsewhere (see Gera and Kuhn, 1977, p. 65), the model was tested to determine whether car-ownership decision is made simultaneously with the residence location decision; however, no support was found from the Toronto CMA data for this hypothesis.

transportation costs. Thus a negative coefficient is expected for N_j. The variable is formulated as follows:

N_j = the percentage of those working in zone j belonging to economic[26] families with more than one wage earner,

$$N_j = \frac{\sum_{i=1}^{63} N_{ij}}{E_j} \cdot 100$$

where N_{ij} = number of workers belonging to economic families with more than one wage earner commuting from residence zone i to zone j.

-- <u>Y_j (the average annual family income at the workplace j):</u>

The effect of an increase in the worker's family income upon journey-to-work distance is ambiguous because of two forces working in opposite directions. Although Y is related to commuting costs through the value of time[27] (which induces workers to reduce journey-to-work distance), it also affects housing demand, if housing is not an inferior good (which encourages greater journey-to-work distance because an increase in income will increase the worker's demand for housing which will tend to move the worker out on to a higher marginal savings in housing expenditure curve and would increase the optimum distance)[28], i.e., $\partial D/\partial Y \gtrless 0$. The

26 'Economic Family', is defined for the 1971 Census as, "a group of two or more persons living together and related to each other by blood, marriage or adoption". For further remarks see Statistics Canada, *Dictionary of the 1971 Census Terms*, Catalogue 12-540, 1972, pp. 6-7.

27 For a detailed discussion, see Gera and Kuhn (1977), pp. 45-48.

28 See Figure 1, *Ibid*, pp. 27-28.

variable is defined as follows:

Y_j = the average annual (economic) family income of workers employed in zone j,

$$Y_j = \frac{\sum_{i=1}^{63} a_{ij} Y_{ij}}{E_j}$$

where Y_{ij} = the annual (economic) family income of workers living in zone i and working in j.

3.1.1(d) Housing Demand Variables

The worker's demand for housing (but not the actual quantity chosen, which, in a theoretical sense, is endogenous in the model)[29] enters the model through the average (economic) family income (Y_j) and family size (FS_j) variables. As already discussed above, the effect of income (Y_j) upon the journey-to-work distance would depend on the relative strengths of the impact of income upon the consumption of housing and upon the marginal value of time.[30] If the impact of income upon the consumption of housing more than offsets its impact upon the marginal value of time, we would expect Y_j to have a positive coefficient.

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29 In our earlier paper (*Ibid* p. 44), we argued that in the residential location model, the residential space consumption and locational decisions should be simultaneous outputs of the worker's decision process. A model was proposed (p. 65, equations 22-24) allowing individuals to simultaneously choose their residential location and quantity of housing (the type of structure of the dwelling unit (TY) and the number of bedrooms (BR)). The proposed model was recursive in the sense that the locational choice variables entered in the determination of the bundle of housing services but the quantity of housing and type of structure did not determine locational choice decisions. The estimation results from Toronto CMA data, however, did not support our hypothesis as the results for the TY and BR equations are not significant.

30 See, Wheaton (1977).

-- FS_j (family size of the worker employed at the workplace j):

This variable will tend, even when income is held constant, to increase the demand for housing which will induce the worker to move farther away from the workplace for the same reasons as argued in context of variable Y_j. Thus, we would expect this variable to be positively related to commuting distance. The variable is formulated as follows:

FS_j = the percentage of workers employed at j in (economic) families of 3 or more persons,

$$FS_j = \frac{\sum_{i=1}^{63} FS_{ij}}{E_j} \cdot 100$$

where FS_{ij} = number of workers commuting from residence zone i to zone j who are part of (economic) families of 3 or more persons.

3.1.1(e) Other Socio-Economic Variables

The other socio-economic variables included in the model are worker's sex and age. Both of these variables, which are considered to have important effects on the journey-to-work distance, are discussed in turn.

-- S_j (sex of the worker):

In several studies,[31] it has been found that male workers tend to travel longer journey-to-work distances than their female counterparts. We would, then, expect this variable to have a positive coefficient. The variable is defined as follows:

S_j = the percentage of workers employed at j who are male,

31 See Taaffe, Garner, and Yeates (1963), pp. 58-62; Wheeler (1967); and Gera and Kuhn (1978) p. 74.

$$S_j = \frac{\sum_{i=1}^{63} S_{ij}}{E_j} \cdot 100$$

where S_{ij} = the number of male workers commuting from residence zone i to zone j.

-- AG_j (age of the worker):

Given the well documented inverse association between age and other dimensions of geographic mobility,[32] we expect a negative relationship between age and distance travelled to work. The variable is formulated as follows:

AG_j = the average age of the worker employed in zone j,

$$AG_j = \frac{\sum_{i=1}^{63} a_{ij} \; AG_{ij}}{E_j}$$

where AG_{ij} = age of the workers commuting from residence zone i to zone j.

3.1.2 The Job Location Model

This model is also tested in terms of the "average" zonal value for each of the variables. The variables included in the model are defined below.

As assumed in the residential location model, subscript i refers to residence location and j to job location, where i, j = 1, 2, ...63. As defined earlier, let,

a_{ij} = number of workers commuting from residence zone i to workplace j,

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32 See Lansing and Mueller (1967); and Long (1972).

d_{ij} = air mile distance between residence zone i and workplace j,

L_i = total number of workers living in residence zone i

or $$L_i = \sum_{j=1}^{63} a_{ij}.$$

Dependent Variable

With the above notations, the *dependent variable* in the job location model is defined as follows:

D_i = average distance of journey-to-work for workers living in the residence zone i,

$$D_i = \frac{\sum_{j=1}^{63} a_{ij} d_{ij}}{L_i}$$

Independent Variables

"Urban Structure" Variables

3.1.2(a) Wage Gradient Variables

We assume that a wage surface, analogous to rent surface, exists in cities. This surface would indicate that earnings should be higher at the central business district (CBD) and should achieve lower peaks at secondary employment centres in order for equilibrium in the labour market to exist.[33] Since the data on actual earnings by zone are available, we do not resort to the use of wage surface proxies based on a theoretical assumption here, but use zonal average earnings levels directly in the calculation of the following variables to

33 See Evans (1973); and Gera and Kuhn (1977), pp. 53, 83-84.

reflect the effect of the urban wage surface. These variables are constructed so as to indicate the extent to which workers living in residence zone i could increase their earnings by taking up jobs at a distance farther from the home zone.

-- WG_i (relative annual average earnings of those working in residence zone i):

According to the theory of job location, one of the crucial determinant of journey-to-work distance is the extent to which a worker can actually increase his (her) earnings by taking a job at a greater distance from his (her) residence site. The variable WG_i is expected to have a negative impact on distance travelled, since the higher the relative earnings level in the worker's home zone, the less the incentive will likely be to take up a job at a greater distance from the home zone. This variable is formulated as follows:

WG_i = average annual earnings of those working in the residence zone i, relative to the average annual earnings in the CMA

$$WG_i = \frac{W_i}{W_{CMA}}$$

where W_i = average annual earnings of workers employed in zone i

W_{CMA} = average annual earnings of all the workers employed in the CMA.

-- WP_i (earnings potential at residence zone i):

This variable indicates the proximity of the worker's residence to high earning areas. On the basis of arguments similar to those given above in case of variable WG_i, this variable WP_i is expected to have a negative coefficient. Earnings potential at zone i is calculated using the formula:[34]

WP_i = earnings potential at residence zone i

$$WP_i = \sum_{j=1}^{63} \frac{W_j}{d_{ij}}$$

where W_j = average annual earnings of workers employed in zone j.

When i=j, d_{ij} was set at unity.

3.1.2(b) Other "Urban Structure" Variables

-- EP_i (employment potential at the residence zone i):

This variable is analogous to the residence potential (RP_j) variable in the residential location model. EP_i indicates the probability of finding a job in the home zone or surrounding zones. This variable is related to the wage surface in the sense that it represents "search costs" for finding a job. High values of EP_i, indicating a greater number of jobs within easy access of the residence site, suggest lower search costs near home zone and hence a shorter journey-to-work. Thus, EP_i is expected to have a negative coefficient.

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34 For a discussion of the calculation of the "Potential" variables, refer to footnote 24, p. 21. Theoretically WP_i should be calculated as follows:

$$WP_i = \sum_{j=1}^{63} \frac{W_j}{d_{ij}^{\alpha}}$$

In this case, the distance deterrence coefficient α was set at unity.

Employment potential at zone i is calculated using the formula:[35]

$$EP_i = \sum_{j=1}^{63} \frac{E_j}{d_{ij}^2}$$

where E_j = total number of workers employed in zone j.

When i=j, d_{ij} was set at unity.

Socio-Economic Variables

3.1.2(c) Transportation Cost Variables

As in residential location model, transportation costs are represented by the variables CO_i and N_i. Note that, although the worker's earnings may affect transportation costs through the money valuation of time, these are not included here because the workers earnings are, in a theoretical sense, endogenous to the job location model.

-- CO_i (workers owning one or more cars at the residence zone i):

In addition to the arguments made in the residential location model, we propose here that car-ownership might affect the search for a job as well. Thus, the car might well be used for seeking a new job and be treated as an argument for search cost. We would expect CO_i to have a positive coefficient.

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35 Refer to footnote 24, p. 21. This variable is calculated as suggested by Hansen (1959); Isard (1960); and Forster (1974). In this case it was found that the performance of this variable/model improved substantially when the distance deterrence coefficient, α, was set at two.

This variable is defined as follows:

CO_i = the percentage of the workers living in zone i belonging to households which own one or more cars,

$$CO_i = \frac{\sum_{j=1}^{63} CO_{ij}}{L_i} \cdot 100$$

where CO_{ij} = the number of workers in households owning one or more cars and commuting from residence zone i to workplace j.

-- N_i (workers belonging to families with more than one wage earner):

As argued in the residential location model, it is expected that the presence of another wage earner in the family by increasing joint commuting costs, will induce workers to reduce their journey-to-work distance. Thus, a negative coefficient is expected. The variable is formulated as follows:

N_i = the percentage of workers living in residence zone i who belong to families with more than one wage earner,

$$N_i = \frac{\sum_{j=1}^{63} N_{ij}}{L_i} \cdot 100$$

where N_{ij} = the number of workers belonging to families with more than one wage earner residing at i and working at j.

3.1.2(d) Other Socio-Economic Variables

As in the residential location model, we recognize the effect of a number of socio-economic and demographic factors that may affect the distance workers are willing to commute.

Certainly, family size would be expected to be important, especially for non-heads, as will occupation, sex and age.

-- FS_i (family size of the worker):

In the job location model, the family size variable cannot be interpreted as reflecting housing demand, as it did in the residential location model. Its relevance here is that larger family size may have a positive effect on the worker's utility of earnings, thus tending to increase distance travelled as workers look farther afield to obtain higher earnings. However, for non-heads of households, the effect of this variable upon journey-to-work distance is ambiguous because of two competing effects -- the "utility of earnings" effect and the "value of time" effect. Since non-heads are more often associated with child-rearing and home responsibilities than heads, we might expect that non-heads would place a greater emphasis on the value of time the larger the size of their families. The greater the value placed on time, the greater the transportation costs and the smaller the commuting distance expected, in relative terms. This variable is defined as follows:

FS_i = the percentage of workers residing in zone i who are in (economic) families of 3 or more persons,

$$FS_i = \frac{\sum_{j=1}^{63} FS_{ij}}{L_i} \cdot 100$$

where FS_{ij} = the number in (economic) families of 3 or more persons commuting from residence zone i to zone j.

-- S_i (sex of the worker):

As argued in the residential location model, we expect this variable to have a positive coefficient. This variable is formulated as follows:

S_i = the percentage of workers living in residence zone i who are male,

$$S_i = \frac{\sum_{j=1}^{63} S_{ij}}{L_i} \cdot 100$$

where S_{ij} = the number of male workers commuting from residence zone i to zone j.

-- AG_i (age of the worker):

As argued in the residential location model, AG_i is expected to have a negative coefficient. This variable is defined as follows:

AG_i = the average age of workers living in residence zone i,

$$AG_i = \frac{\sum_{j=1}^{63} a_{ij} \; AG_{ij}}{L_i}$$

where AG_{ij} = the age of the workers commuting from residence zone i to zone j.

-- O_i (occupation of the worker):

Although an income variable could not justifiably be used in the job location model (because, as noted above, income, in a theoretical sense, is endogenous to the model), it was thought that an approximation of the worker's income earning ability such as occupation, could be useful. Theoretically, the impact of this variable is multidimensional, so its expected sign is ambiguous. If blue-collar workers have a lower income-earning ability, one would expect the lower money value of travel time and higher marginal utility of income for this group to encourage longer journeys-to-work. On the other hand, analysis in another paper by the authors[36] indicated that, due to a tendency of blue-collar residential areas and job sites to coincide in the Toronto CMA, long-distance commuting was significantly less prevalent among blue-collar workers than among white-collar workers. Thus we might expect this latter effect to dominate here as well, producing a negative coefficient for the occupation variable. This variable is defined as follows:

O_i = the percentage of workers residing in zone i who are blue-collar (skilled and unskilled "manual" and "crafts and trades" occupations),

$$O_i = \frac{\sum_{j=1}^{63} O_{ij}}{L_i} \cdot 100$$

where O_{ij} = number of blue collar workers commuting from residence zone i to zone j.

3.2 Model Specification

There is no theoretical justification for believing *a priori* that the relationship between our variables is linear. Moreover, an inspection of scatter diagrams between several independent variables and the dependent variable indicated the

36 See Gera and Kuhn (1978).

inappropriateness of attempting to fit a linear relationship to the data. Thus, both models are tested in non-linear forms.

Preliminary considerations suggested that a double-log form would be the most appropriate one for two reasons. First, it directly produces an estimate of the point elasticity from the regression coefficients,[37] which provides information on the percentage change in the endogenous variable resulting from a one per cent change in an exogenous variable. Secondly, this form helps to correct for possible heteroscedasticity. As we are dealing with grouped data, the error terms cannot be expected to be homoscedastic[38] and moreover, there is a possibility of an error or bias in the estimation results caused by the variation in zone sample sizes. The logarithmic transformation corrects this type of heteroscedasticity.

In the process of estimation, it was found that for the residential location model the double-log form did indeed provide the best fit to the data. For the job location model, however, it was found that the semi-log form, when the socio-economic variables entered into the equation untransformed, yielded the best fit to the data. Thus, except for the socio-economic variables the equation is linear in logarithms to allow for direct estimates of point elasticities and also to control for heteroscedasticity.

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37 See Johnston (1972), pp. 51-52.

38 See Cramer (1971), pp. 143-146.

The models or estimating equations[39] are as follows:

Residential Location Model

$$\log D_j = a_0 + a_1 \log(1/DC_j) + a_2 \log ED_j + a_3 \log SI_j + a_4 \log RP_j + a_5 \log CO_j + a_6 \log N_j + a_7 \log Y_j + a_8 \log FS_j + a_9 \log S_j + a_{10} \log AG_j$$

Job Location Model

$$\log D_i = b_0 + b_1 \log WG_i + b_2 \log WP_i + b_3 \log EP_i + b_4 CO_i + b_5 N_i + b_6 FS_i + b_7 S_i + b_8 AG_i + b_9 O_i$$

These equations are estimated with the least-squares multiple regression (OLS) technique. A measure of the accuracy of the model is obtained by the use of $\bar{R}^2$ with F ratio and the t-statistics of the regression coefficient in the estimating equation in conjunction with the average absolute percentage

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39 The choice of the proxies for the two categories of the variables -- the "urban structure" variables and "socio-economic" variables -- and the subsequent emergence of our final equations was an evolutionary process. In this process it was necessary to run a substantial number of regressions. This is understandable in the face of the absence of more directly relevant data when one has to rely on suitable proxies consistent with the underlying theoretical structure. To aid in the evaluation of results discussed in the next section, the performance of the alternative proxies used in some of our regressions is also pointed out at the appropriate places.

error (AAPE).[40] The AAPE is calculated as follows:

$$AAPE = \frac{1}{n} \sum_{j=1}^{n} \left| \frac{D^e - D^a}{D^a} \right|$$

where D^e = the estimated value of D (the journey-to-work distance),

D^a = the actual value of D,

n = total number of zones used in the model.

The AAPE is a measure of the deviation of the estimated value of the dependent variable from its actual value, in percentage terms.

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40 For a good discussion of this error statistic, see Klein (1971).

Section 4: Empirical Results

In this section, we present estimation results of the testing of the residential location and job location equations, for household heads and non-heads together and separately. We shall emphasize two aspects:

(i) the importance of location-rents, wage gradients and other "urban structure" variables in the respective models, and

(ii) the influence of socio-economic characteristics of workers in the residence and job location decisions.

The estimation results are presented in Tables 1 (p. 40) and 2 (p. 58). Looking first at the overall fits for the equations, we find that $\bar{R}^2$ values range from 0.719 in the residential location model for non-heads, to 0.908 in the job location model for heads. Secondly, the average absolute percentage error ranges from 6.06 in the total sample (both heads and non-heads of households together) residential location model, to 8.44 in the job location model for heads. We judge these overall results as highly significant for an urban cross-section study. Thus, the models succeed, to a great extent, in explaining the variations in journey-to-work distance. This encourages the belief that the general form of the models is most satisfactory and capable of evaluating residential and job location decisions of individuals. Thus, such models could be of assistance in an urban area's development planning. Even so, great care must be exercised in interpreting the empirical results obtained, especially those for the socio-economic variables, among which the correlations are high.

4.1 The Residential Location Model

Table 1 presents the results for the residential location equation: the coefficients are in the form of elasticities. The most important results in this table are the strong and significant effects of the elasticity between commuting distance and the distance of the workplace from the core of the city and between commuting distance and residential opportunities. This suggests that urban structure exerts a strong influence on commuting patterns. Among the socio-economic variables, age is important in the regression results while other variables perform weakly.

Looking first at the "urban structure" variables ($1/DC_j$, ED_j, SI_j, and RP_j), we see that their signs are as expected.[41] Workplace distance from the central business district (CBD) had a significant effect on commuting distance in all equations. As noted previously, the inverse of workplace distance from the CBD is interpreted as a proxy for marginal savings in location-rent. We find that for the total sample (equation 1 in Table 1), the average commuting distance decreases 0.21 per cent with a 1 per cent increase in the location-rent proxy, when all other exogenous variables are held constant. For heads of households (equation 2 in Table 1), a 1 per cent increase in the proxy

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41 In addition, a rent variable (average rent paid by the workers at the work zone j -- imputing the value of rent to owner-occupied dwellings) was tested as a proxy for rent gradients but found to be of no significance in this model. This might be due to the problem of holding housing "quality" constant when measuring the variation in rents.

Table 1

ESTIMATION RESULTS: RESIDENTIAL LOCATION MODEL EXPLAINING LOG (D_j) BY HOUSEHOLD STATUS, HEADS AND NON-HEADS

Dependent Variable	Regression Coefficients (t-values in parentheses) — Independent Variables											$\bar{R}^2$*	F-Statistic	AAPE (Average Absolute % Error)	Mean value of dependent variable	Number of observations
	log ($1/DC_j$)	log ED_j	log SI_j	log RP_j	log CO_j	log N_j	log Y_j	log FS_j	log S_j	log AG_j	Constant					
(1) Total (Both Heads and non-Heads of Household) log D_j	.214 (4.86)	-.008 (-.55)	-.066 (-.96)	-.731 (-13.25)	-.047 (-0.08)	.031 (0.09)	.547 (2.09)	-.129 (-0.45)	.552 (2.49)	-1.181 (-3.25)	8.044 (3.28)	0.898	47.16	6.06	4.73	63
(2) Heads of Household log D_j^H	.178 (3.95)	-.014 (-0.74)	-.034 (-0.40)	-.604 (-8.72)	-.151 (-0.26)	.196 (0.75)	.363 (1.54)	-.341 (-0.86)	1.004 (1.28)	-1.222 (-2.73)	6.981 (2.07)	0.820	25.07	7.32	5.09	63
(3) Non-Heads of Household log D_j^{NH}	.234 (3.72)	-.002 (-0.09)	-.039 (-0.47)	-.633 (-7.66)	-.045 (-0.08)	-.416 (-0.74)	.482 (1.61)	-.118 (-0.35)	.131 (1.13)	-1.579 (-3.21)	11.998 (3.21)	0.719	16.07	8.13	3.67	63

*In a double-log form (or a semi-log form when the dependent variable is in logarithmic form) fit, the R^2 measures the proportion of the variation of the log D_j that has been accounted for, which is not the same thing as the proportion of the variation of D_j. Thus to put the double-log equation on a comparable footing with one that simply has D_j as regressand, we took antilog of calculated values of log D_j and find their $\bar{R}^2$ with the observed values of D_j. See Goldberger (1964), p. 217.

Source: Statistics Canada and estimates by the authors.

variable results in an increase of 0.18 per cent in commuting distance, and for non-heads of households (equation 3 in Table 1), a similar increase raises commuting distance by 0.23 per cent. Thus, the positive coefficient for $1/DC_j$ indicates that, *when other factors are held constant*, home-work separation tends to decrease at a decreasing rate with the distance of the workplace from the CBD.[42] This is the relationship one would expect given the postulated relationship of location-rents to distance from the city centre.

The other location-rent proxy, employment density at the workplace (ED_j), which was intended to capture the effects of non-CBD employment concentrations on location-rents and thus on commuting distance, is insignificant in all cases. Attempts to replace this variable with other proxies to capture the minor peaks in the rent surface also failed.[43] This suggests that, although employment in the Toronto CMA is quite decentralized away from the core,[44] this decentralization has not created variations in location-rents significant enough to have any effect on the residence location decision of workers. The

42 One might conclude from this result that the decentralization of employment opportunities away from the city centre in the Toronto CMA will tend to reduce the average journey-to-work distance. Such a conclusion is, however, subject to an important qualification, discussed on p. 50-51.

43 Among these, E_j (total employment in the zone of work) was used in the model and also found to be insignificant. This variable was used in the same context by Beesley and Dalvi (1974). Also see Kain (1964), footnote 6, p. 58.

44 See Gera, Betcherman, and Paproski (1978), pp. 16-19.

reasons for this become apparent when we examine the geographical distribution of employment density in the Toronto CMA (see Figure 2 on p. 53). The employment density seems to decline in all directions from the CBD. No clear secondary nodes of employment activity seem to be evident.[45] Thus it appears that variation in location-rents seem to be mainly determined by distance from the CBD in the Toronto CMA.

Looking next at the service industry concentration variable, SI_j, we find that it is not significant in any of the equations of the residential location model. This indicates that this residential amenity variable did not have any significant effect on the residential location decision of workers.

Another variable, residence potential at the workplace (RP_j), which indicates the overall availability of residences near the job site and hence the probability that a worker can find a suitable residence near his place of work, is highly significant (absolute t value greater than 7.66 in all equations) and the most powerful of all the explanatory variables. The effects of search for a specific type of housing seem to be captured by the RP_j variable in this model. Of the structural variables, this variable has the largest elasticity at the sample mean for the commuting distance D_j in all the equations.

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45 If the density of employment is a function of distance from the CBD, the rent surface will be approximately conical in shape, with the steepness of the surface of the cone varying inversely with distance from the CBD. Thus, residence-workplace separation would depend mostly upon the relative location of workplace and the CBD, the level of employment at the workplace being an insignificant factor in itself. See Evans (1973), p. 214.

As expected the elasticity coefficient for this variable indicates that the more existing residences that are available near the zone of work, the shorter will be the average journey-to-work.

Of the socio-economic variables, both variables relating directly to transportation costs (CO_j and N_j) were found to be insignificant in all the equations of the model. The elasticity coefficients for these variables with respect to commuting distance are not significantly different from zero. It should be emphasized that car-ownership is measured per household rather than per worker. The insignificance of this variable is probably related to the overriding impact of urban structural factors embodied in RP in the model, in the sense that workers employed in areas of low residence potential (especially the outer suburban and peripheral areas) are likely to *need* a car for this very reason. Thus car-ownership seems to be not so much an exogenous determinant of work-trip distance as it is simply another concomitant of the urban structural factors which do play such an important role in commuting. Thus, our results do not support the hypothesis of Beesley and Dalvi (1974) that car-ownership has an independent role to play in the residential location model. It should be noted that they could not test this hypothesis due to absence of data on car-ownership.

Family income (Y_j), which is also related to transportation costs, has a significant positive effect on commuting distance (absolute t value greater than 2.0) in equation 1 (total sample heads and non-heads of households together) in Table 1. This indicates that in the residence location decision, the effect of income on housing demand outweighs its effect on the value of time, leading higher income workers to consume more residential space at a greater distance from the workplace. Specifically the total sample results show an average income elasticity of commuting of .55; in other words, holding other factors constant, a doubling of family income implies an increase of over 50 per cent in commuting distance in the Toronto CMA.[46] However, because the income coefficients fail to satisfy a two-tailed t-test at the 5 or 10 per cent significance level in the heads and non-heads equations, less confidence is attached to the effect of this variable, since there seems to be a lack of strong regularity in its effect.[47]

Contrary to the predictions of the residential location theory, we find that family size did not have a positive effect on commuting distance as the elasticity coefficient is not significantly different from zero in any of the equations.

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46 Stucker (1975) also found a similar average income elasticity of commuting (0.59) in his study of commuting in San Francisco.

47 While the association between income and home-work distance is not relatively robust, our observations in this context reveal a strong association between income and the distance of the residence site from the core in the Toronto CMA. This suggests that the impact of income on journey-to-work distance observed in the model here is in fact an *indirect* one, due mostly to the choice of a residence with respect to the city centre. Given that location-rents are determined mainly by distance from the core, as we noted earlier, this is not an unexpected result. Indeed in another paper (Gera and Kuhn, 1978), it was found that occupation which is probably highly related to income, seemed to have little direct impact on the journey-to-work distance. The main determinant of journey-to-work distance were found to be urban locational constraints.

In other words, holding other exogenous variables constant, an increase in family size does not seem to influence the worker's decision to live farther from the job site through its impact on the demand for higher residential space consumption. This result, which is contrary to expectations, may be due to several factors, among them the possibility that the effects of changing family structure and composition over the life cycle are more adequately captured by the age variable. Moreover, it may be that, since rent gradients seem to be relevant only in relation to the CBD in the Toronto CMA,[48] the housing space demands influence location with respect to the *CBD* more so than with respect to the workplace.

Looking at the sex (S_j) variable, a positive coefficient significant at the 95 per cent level, is found for the total sample (equation 1). This indicates that, as expected, zones where a greater percentage of the workforce was male exhibited higher commuting distances than those where female workers are more important. Although the coefficient of this variable has the same sign in the models for heads and non-heads, it is not statistically significant even at the 90 per cent level. An obvious reason for this result is the fact that, since the category of "household heads" is, by definition, overwhelmingly male, and that of "non-heads" largely female, the variation in sex composition by zone *within* these groups, as compared to between these groups (which is captured by the S_j variable in the "total" model) is not significant enough to affect mean commuting distance by zone.

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48 For a discussion on this point, see p. 50-51.

Finally, age (AG_j) had the most significant effect of all the socio-economic factors on commuting distance in every equation (coefficient significant at the 99 per cent level). This shows then, that as expected, commuting distance tends to decrease with age. Moreover, this variable has the largest elasticity at the sample mean of all the socio-economic variables for the average commuting distance, with all other exogenous variables held constant. Thus, counter to the results of Clemente and Summers (1974), we do find support for the much discussed inverse relationship between age and distance travelled to work.

Summary and Conclusions

In summary, empirical testing of the residential location model from 1971 Toronto CMA data only partially confirms the validity of the theoretical model of residential location. Although this model predicts that the main factors determining home-work separation will be the variation in location-rents, transportation costs, and housing demand, our empirical results provide only qualified or limited support for the importance of location-rents and housing demand. More specifically;

(i) The "urban structure" variables are the most important determinants of the journey-to-work in the residential location model. Location-rents prove to be significant for the individual's residential location decision-making process, but the amount of marginal savings in location-rents available to the worker is determined only by workplace distance from the CBD. Secondary employment centres did not affect the residential location decision through the bidding-up of location-rents. The most powerful factor in determining home-work separation is found to be residence potential, which is only indirectly related to the concept of location-rents through the element of "search costs".

The performance of the "urban structure" variables in our model support the findings of Sheldon and Hoermann (1965) that metropolitan structure has a strong influence on commuting patterns.[49] The strong performance of the residence potential variable suggests that the collective residential opportunities are a strong determinant of the residential location while the other factor, level of concentration of service industries, is less important. The value of the RP variable indicates the overall

49 Wolforth (1963) concluded from his Vancouver study that the journey-to-work is a result rather than a cause of urban spatial structure.

availability of residences near the job site and hence the probability that a worker can find a suitable residence near his place of work. Thus, the factor of *selection*, or *choice* for the specific attributes of the residence desired becomes important.

(ii) Variation in transportation costs, as embodied in the CO and N variables, did not seem to have an important exogenous impact on commuting distance.

This suggests that transportation costs, as captured by these variables, do not play a significant role in the residence location decision. This, of course, does not necessarily imply that the level of transportation costs *per se* is not an important consideration in the individual's journey-to-work decision, but it does cast some doubt on the proposition that, in Toronto, individuals are tightly constrained by such factors in their choice of a residence vis-à-vis their workplace. This reflects the relative decline in the importance of urban transportation costs to the individual that has occurred in the post-war period in all of North America (due to mass car-ownership, heavy public investment in transportation infrastructure, etc.).

(iii) The effect of housing demand on commuting distance is not apparent through the family size variable, which is used as an indicator of space preference, but did seem to play a role through the family income variable, causing a positive income elasticity of commuting of 0.54 when the total sample is considered. This income effect on commuting becomes weaker when the model is tested for heads and non-heads of households separately.

(iv) The other socio-economic characteristics (age and sex) have some impact on journey-to-work distance.[50] Age of the workers is found to be the most significant in directly affecting average journey-to-work distance when other factors are held constant. Sex is also found to have a significant effect on journey-to-work distance in the total sample results, although the effect of this variable, for reasons explained earlier, becomes weak when the model is tested for heads and non-heads of households separately.

(v) The model results do not provide any strong support for our hypothesis that the residential location model will be more applicable to primary than secondary wage earners.

In general, no striking differences in the commuting behaviour of the two subpopulations are noticeable from the model results for heads and non-heads of households; nonetheless, two observations are worth mentioning. First, the "heads" model has a slightly higher $\bar{R}^2$ and lower AAPE than the "non-heads" model; however, on this basis alone it is inappropriate to conclude that the residential location model is more applicable to heads than to non-heads. Secondly, for non-heads there is slightly higher elasticity for two significant urban structure variables (1/DC and RP) with respect to commuting distance. If this difference is at all significant it may indicate that non-heads are slightly more sensitive than heads to these urban structural constraints in their commuting behaviour.

We turn now to an evaluation of the implications of our findings in context of standard residential location theory.

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50 We suspect that in a multiple regression model, without controlling for "urban structure" variables, any theoretical or empirical analysis examining the relationship of journey-to-work distance and socio-economic characteristics of worker (see for example, Hecht, 1974; Gayler and Kayser, 1977), might be misleading in evaluating latter's quantitative relationship to journey-to-work distance.

The model results lead to an impression that some aspects of the economic models of Alonso (1964) and Muth (1969) require re-assessment and modification in order for them to be more realistically applicable to the Canadian context, and, in particular, to the Toronto CMA. The monocentric model of a city is quite inappropriate today, given the widespread distribution of employment in most modern cities. To accommodate this change in reality, several basic revisions to the monocentric model have been proposed in the literature. While these attempts have been reviewed by the authors in detail elsewhere,[51] we briefly recall them here in order to assess their validity in light of our model results.

First, means of extending the monocentric model were used by Kain (1962) who proposed that in a city with decentralized employment opportunities, the *level* of location-rents would still be a function of distance from the city centre, and therefore, the *marginal savings in location-rents* available at the workplace would be a declining function of the workplace's distance from the core. Thus, *ceteris paribus* journey-to-work length in such a city would tend to decrease with workplace distance from the CBD.

This proposition receives considerable support from the performance of the variable (1/DC) in our model. The reciprocal of DC seems to provide an effective proxy for the marginal savings in location-rents available; its effect on commuting distance is significant and in the expected direction.

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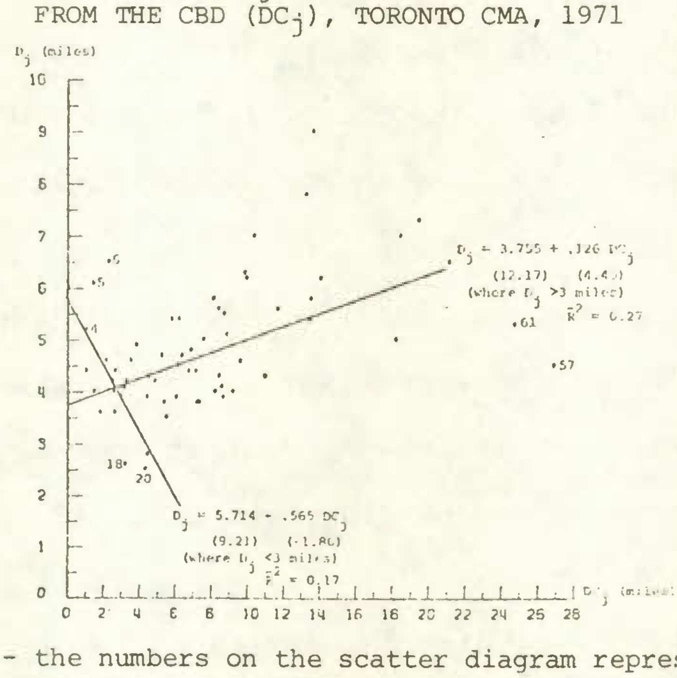
51 See Gera and Kuhn (1977).

There is, however, an important qualification regarding the effect of this variable which becomes apparent when the data are examined more closely. Figure 1 below indicates that the predicted effect of location-rents on commuting distance seems to be confined to zones within a three-mile radius of the CBD where the journey-to-work distance decreased the further the place of employment was from the CMA centre. Outside of this three-mile radius, there was a gradual increase in commuting distance. The average commuting distance at the peripheral workplaces was 6.0 miles as compared to 5.7 miles at the CBD.[52] This is explained by large zone size, vacant land and the low values of residence potential (RP) in the peripheral areas (east sector, north sector, and west sector - see Map 1),

Figure 1

RELATIONSHIP BETWEEN MEAN COMMUTING DISTANCE AT THE PLACE OF WORK (D_j) AND WORKPLACE DISTANCE FROM THE CBD (DC_j), TORONTO CMA, 1971



Note - the numbers on the scatter diagram represent the respective zones (see Map 1)

- t-values in parentheses

Source: Statistics Canada and estimates by the authors.

52 See Gera, Betcherman, and Paproski (1978), p. 122.

combined with the generally higher speed of travel in those areas. All of these contribute to longer mean commuting distances at the peripheral workplaces.

Secondly, another possible extension of the monocentric model, proposed among others by the authors, complements Kain's (1962) framework by considering that the movement of employment to suburban areas might create secondary nodes of activity, where location-rents are bid up to higher levels than in immediately surrounding areas. In this case, we would expect marginal savings in location-rents, and hence journey-to-work distance, to be a positive function of the level of employment concentration around a particular workplace.

This new proposition does not appear to be supported by the model tested here, since neither of the indicators of the level of employment concentration at the workplace that were tested, ED_j and E_j had a significant effect on commuting distance. Figure 2 suggests one of the reasons why this may be the case since it shows that employment density declines in all directions from the CBD.[53] Indeed, our observations and model results suggest that despite the high degree of suburbanization of employment opportunities in the Toronto CMA, this has not led so much to the development of secondary employment *centres* where rents and densities have been bid up to higher levels, but to the existence of a *spread* pattern of employment, characterized by low-density industrial parks or office areas that use larger quantities of relatively cheap land. Thus, the different nature of land use by suburban employment-generating

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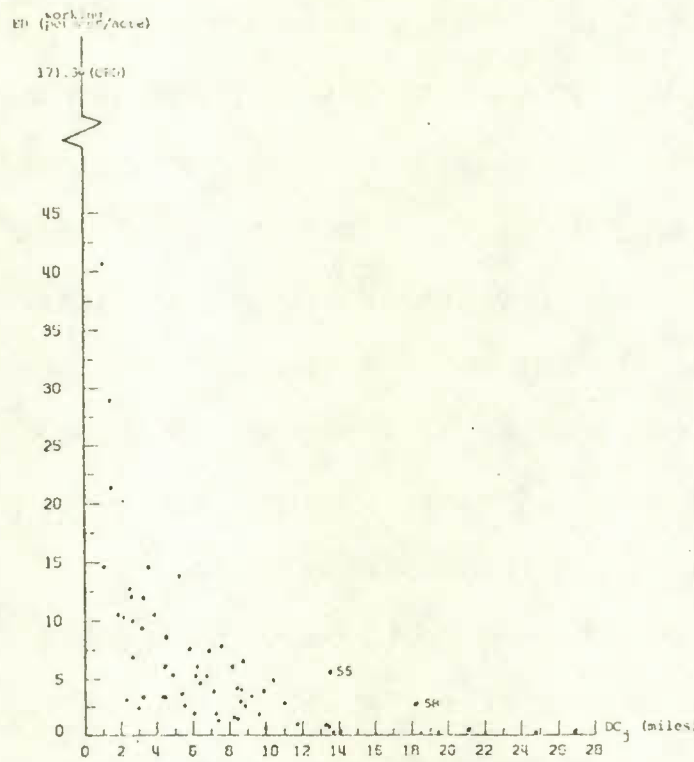
53 See footnote 45, p. 42.

Figure 2

RELATIONSHIP BETWEEN EMPLOYMENT DENSITY BY ZONE (ED) AND ZONAL DISTANCE FROM THE CBD (DC_j), TORONTO CMA, 1971



Note - the numbers on the scatter diagram represent the respective zones (see Map 1)

Source: Statistics Canada and estimates by the authors.

activities implies that the second extension of the monocentric model noted above is not applicable in Toronto CMA. Further revision of the monocentric model thus seems necessary if new theoretical constructs are to apply more accurately to this Canadian metropolitan area.

Thirdly, the strong performance of the residence potential (RP) variable, suggests the importance of the incorporation of the element of *choice* of residence and its attributes explicitly in the models of residential location.

Finally, the relative decline in the importance of urban transportation costs, as suggested by model results, is an important development that has not been, but should be incorporated into the monocentric models of urban structure and commuting. This observation also helps to explain why the secondary peaks in location-rent surface are not likely to be significant. To elaborate this point let us consider what would change in a city of monocentric type if transportation costs suddenly dropped. First, a major shift in urban structure would occur over time. With cheap intra-urban costs, the incentive for employment-generating activities to locate next to one another at a central node would be removed, and accordingly, much of the economic activity in the city would move to suburban locations on cheaper land. Activities which remained in the core would be those with the highest needs for mutual accessibility (head offices, etc.), and if the city grew rapidly enough the expansion of these activities might well be enough to maintain the originally steep rent gradient around the CBD. The activities which move to the suburban areas, however, would form employment patterns very different from the CBD. Employment would be dispersed, in a low-density pattern, geared to access by car. There would be no incentive for secondary nodes of activity to arise; cheap transportation implies that secondary peaks in the location-rent surface are not likely to be significant.

These observations coincide remarkably well with our results relating to "urban structure" and transportation costs. As we noted for the Toronto CMA, those with workplaces in the CBD tend to commute longer-than-average distances because of the rent gradient around the CBD. Workers with non-centrally-located workplaces (particularly in the periphery), however, seem to face a different set of considerations in their "commuting decision". Indeed the performance of the RP variable in the model reveals that, especially for these workers, who face both low transportation costs and the lack of a significant rent gradient, the predominant determinant of journey-to-work length is the factor of *selection*, or *choice*, of residential attributes. In other words, the worker's residential location decision is determined less and less by the transportation cost-housing cost tradeoff, and more and more by the search for housing with specific attributes (type, size, physical and social environment). Thus, contrary to the predictions of the economic theory of residential location (that one would expect lower commuting distances for the workplaces farther from the CBD), the commuting distances in the Toronto CMA tend to increase from low levels in intermediate zones (outer three boroughs: North York, Scarborough, and Etobicoke, see Map 1) to very high levels for workers employed at the peripheral workplaces. As explained earlier, this is due to the fact that the geographically nearby availability of residential opportunities is less in the peripheral areas of the CMA than in the more central areas.

Most of the trends noted above have been foreseen by some of those doing research on urban concerns, but these considerations do not seem to have been synthesized and operationalized in any significant manner. Economists have shown that lower transportation costs will tend to increase the dispersal of the activities in the metropolitan areas,[54] and have long

54 Borukhov (1975); and Wheaton (1974).

maintained that the commodity "housing" can be best considered as a "bundle of attributes" some of which are the attributes of the site itself.[55] Webber (1963), a sociologist, combined these two considerations by proposing "If our speculations concerning the secular declines in these [transportation] costs should prove to be valid, we can expect that the non-transportable on-site amenities will come to predominate as locational determinants" (p. 806). Indeed, this is what our model results are implying.

In conclusion, we admit that our model has certain limitations although it has yielded satisfactory results in an attempt to explain the decision concerning location of residences in an urban area (particularly in terms of low average absolute percentage error for a cross-section study). Perhaps the greatest limitation is that, being an urban cross-section study, it does not recognize the problems of time and dynamics. Despite this, the model can quite possibly be adaptable to other Canadian cities with a few modifications (if needed) for the purposes of understanding the potential effects of new employment-generating and residential development activities on commuting distance and travel demand.

4.2 The Job Location Model

Table 2 presents the empirical results for the total sample as well as for household heads and non-heads separately. A general inspection of the results shows first of all, that the explanatory power of the job location model is somewhat higher than that of residential location model. Secondly, a

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55 Lancaster (1971).

very interesting pattern is revealed comparing heads and non-heads results. The most striking difference is the greater relative importance of "urban structure" variables (in this case WG_i) for heads and of socio-economic factors for non-heads. This becomes more apparent when we consider the effects of these variables below.

The first proxy for the wage gradient, WG_i (relative annual earnings of those working in residence zone i), is found to be significant with the expected (negative) sign for the total sample (equation 1) and heads of households (equation 2), but is insignificant for non-heads (equation 3). This result seems to indicate an important difference in the commuting behaviour of heads and non-heads of households. We know that the mean commuting distance travelled by non-heads is significantly less than that travelled by heads;[56] as well, our model indicates that the former's commuting distance is less sensitive to the level of earnings in the home zone. Thus the greater mean commuting distance of heads may be partially explained by the tendency for household heads to work farther from home if earnings near home are low and closer to home if they are high, and the tendency for non-heads to work closer to the home zone regardless of the level of earnings.

The other wage gradient proxy, WP_i (earnings potential at residence zone i), is insignificant in all the models;

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56 In Toronto CMA in 1971, the initial data shows that heads of households travelled an average of 5.7 miles to work compared to non-heads who travelled an average distance of 4.1 miles.

Table 2

ESTIMATION RESULTS: JOB LOCATION MODEL EXPLAINING LOG (D_i) BY HOUSEHOLD STATUS, HEADS AND NON-HEADS

Dependent Variable	Regression Coefficients (t-values in parentheses) Independent Variables										$\bar{R}^2$*	F-Statistic	AAPE (Average Absolute % Error)	Mean value of dependent variable	Number of observations
	log WG_i	log WP_i	log EP_i	CO_i	N_i	FS_i	S_i	AG_i	O_i	Constant					
(1) Total (Both Heads and non-Heads of Household) log D_i	-.430 (-2.01)	.058 (1.07)	-.216 (-7.42)	-.0039 (-1.04) EC**=.10	.0031 (0.59) EC=-.42	.00866 (2.08) EC=.69	.0065 (0.80) EC=-.51	-.0141 (-1.69) EC=-.77	-.0070 (-2.84) EC=-.10	3.23 (3.76)	0.904	60.50	7.28	4.58	63
(2) Heads of Household log D_i^H	-.553 (-2.26)	.059 (0.96)	-.222 (-6.93)	.00056 (0.16) EC=.20	-.00068 (-0.15) EC=-.20	.0061 (1.53) EC=.46	.0053 (0.58) EC=-.30	-.0076 (-0.99) EC=-.45	-.0015 (-0.71) EC=-.0037	2.97 (3.30)	0.908	56.15	8.44	5.15	63
(3) Non-Heads of Household log D_i^{NH}	-.185 (-0.91)	.022 (0.40)	-.221 (-8.40)	-.00815 (-2.36) EC=-.34	-.00143 (-0.27) EC=-.41	.0129 (3.23) EC=.69	.0061 (1.21) EC=.09	.0188 (1.83) EC=.20	-.0116 (-5.02) EC=-.24	3.11 (4.19)	0.848	37.86	7.48	3.99	63

*refer footnote to Table 1

**EC represents elasticity coefficient

Source: Statistics Canada and estimates by the authors.

alternative forms of the variable[57] are also found to be unsuccessful. This lack of significance may be due to the inadequacy of the variable as a proxy for the actual "earnings-distance opportunities" facing the worker, or may simply indicate that workers do not, in general, make the type of detailed earnings-distance comparisons implied by the theory -- except, as we noted above, for assessing the relative earnings level in the home zone.

Employment potential (EP_i) is the most powerful variable (absolute t-value greater than 6.93 in all equations) in all three equations of the job location model. The influence of this variable in this model is parallel to that of the residential potential variable in the residential location model. The EP_i variable indicates the probability of finding a job (presumably of a given type) in or near the home zone. In a sense, then, this variable captures the influence of "search costs" and job "choice" in this model. As expected, the elasticity coefficient for this variable indicates that the greater the availability of employment opportunities near the zone of residence, the shorter will be the average journey-to-work.

The remainder of the variables in the job location model seem to require cautious interpretation, because of several problems they present. These problems are reflected in the rather inconsistent behaviour of the variables as we shall note below.

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57 For example, using a value of two for the distance deterrence coefficient α in calculating the variable -- as discussed in footnote 34, p. 29.

For household heads (equation 2), none of the transportation cost variables or other socio-economic characteristics are significant, implying that the high explanatory power of this model is due almost entirely to the influence of two features of the urban structure -- relative earnings and the employment potential in the zone of residence. The simple fact that a worker is the primary wage earner for a family, then, seems to overshadow the effect of other socio-economic characteristics in determining the basis on which the job location decision is made.

The model results for the total sample (equation 1) and for non-heads of households (equation 3), are quite similar relative to the results for the heads of households (equation 2). There are, however, some differences between the results for the total sample and for non-heads. For example, although both variables relating directly to transportation costs (CO_i and N_i) are found to be insignificant in the total sample model, the car-ownership variable is significant and has a negative sign in the "non-heads" model (equation 3). The unexpected sign of CO_i suggests that car-ownership would reduce the journey-to-work in this model. This counterintuitive performance of CO_i is probably related to the overriding impact of the urban structural factor EP_i, the zero order correlation coefficient between these two variables being -.81.

The significant positive effect of the family size variable in the total sample (equation 1) might be explained by the higher utility of earnings associated with greater family size tending to increase the distance travelled. In the "heads" model, the coefficient of this variable is positive but not significant at any acceptable level, while that for non-heads is positive, larger than the coefficients for the other two equations, and significant at the 99 per cent level. We note that this result for non-heads is contrary to our expectations in the sense that the "value of time" effect was expected to weigh more heavily for non-heads than for heads relative to the "utility of earnings" effect, so that the coefficient for non-heads might have been expected to be less positive than that for heads, or even negative (our expectations were based on the idea that the greater child-rearing and other home responsibilities of non-heads in larger families might cause them to place a greater weight on the value of time than heads, thus in relative terms, increasing transportation costs and shortening commuting distance). This result could be due to those workers in the non-heads category who might exhibit a considerably greater utility of income because they are members of families where resources are thinly spread, or to the fact that the family size variable itself, which measures the prevalence of families with children in the zone, is actually reflecting the impact of many other causative factors -- especially the predominance of a "suburban life style", an issue to be discussed later, with its concomitant higher commuting distances.

The sex (S_i) variable has the expected directional effect on the commuting distance but the coefficient is not significant in any of the equations of the model. Looking at the age (AG_i) variable, we note that although it has a significant (at the 90 per cent level) negative effect on the commuting distance for the total sample as expected, its significant positive effect for the non-heads is contrary to our expectations. It may have to do with wives re-entering labour market after child-bearing years having to work from fixed location to find desired and appropriate jobs while younger non-heads may be less "choosy" and find jobs nearer where they live.

Finally, occupation (O_i) has the most significant effect of all the socio-economic factors on commuting distance for the total sample and non-heads (coefficient significant at the 99 per cent level) showing the tendency of blue-collar workers' residences and jobs to cluster in the same area of the city. This result is consistent with our findings in another paper which focussed specifically on occupation and commuting distance in the Toronto CMA.[58]

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58 See Gera and Kuhn (1978).

Summary and Conclusions

In summary, empirical testing of the job location model for the Toronto CMA data provides a limited degree of support for the validity of the underlying theory of job location. The theoretical model predicts that the factors that affect residence-work distance in this model fall under three main categories: the wage surface, transportation costs, and other socio-economic variables. Our findings provide only qualified support for each of these categories. More specifically;

(i) The "urban structure" variables are the most influential in affecting the home-work distance in the job location model. The "wage gradient" proved to be an important factor in the journey-to-work behaviour of household heads, but not of non-heads. The relative level of mean earnings in the home zone is taken more into account by the workers than the zone's general proximity to high earnings areas. But the most important factor in determining home-work separation is found to be employment potential, which captures the "search cost" aspect of job choice.

The strong performance of the employment potential variable suggests that the collective employment opportunities are a major determinant of job location. As we argued with respect to the residential location model, the relative decline in the importance of urban transportation costs (due to mass car-ownership and other related factors) has made the worker's search for a job of a given type (occupation, working conditions, etc.) a crucial determinant of his (her) job location. Thus, the factor of availability and *choice* for the type of employment desired becomes important and this is reflected in the strong performance of the employment potential variable.

(ii) Transportation costs did not seem to have an important effect on the commuting behaviour of household heads. Although the car-ownership variable is significant for non-heads, its influence is in a direction opposite to that expected, this result likely being due to the overriding impact of the urban structural factor which we have labelled 'employment potential'.

The above two observations suggest that the worker's job location decision is determined less and less by the transportation cost-potential earnings tradeoff and more by the distribution of employment opportunities and the factor of job *choice*.

(iii) The socio-economic attributes did not show any significant effect on the commuting distances of household heads. For non-heads of households, occupation is found to be the most important factor, among other socio-economic attributes influencing the journey-to-work distance.

The insignificance of socio-economic variables in the "heads" model and unexpected performance of the age variable in the "non-heads" model lead us to a consideration of the interrelated problems of multicollinearity and of the uncontrolled impact of spatial factors, which are particularly serious in this model. These problems result from the fact that, in an analysis involving social and economic characteristics of the resident population in a single, relatively self-contained metropolitan area such as Toronto, almost all of the factors studied tend to be functions of one very crucial spatial consideration -- the distance from the city centre. This is particularly true when the data are taken on a "zonal average" basis, as is the case here. What this reflects is not so much the simple causative effect of distance from the centre on these factors, but a very complex set of relationships among social, spatial, and economic factors which create a general association between lifestyle and urban location. In a generalized depiction of lifestyles, we might distinguish an "urban" lifestyle, -- characterized by more centralized location, lower rates of car-ownership, more families with two or more earners but, at the same time, smaller family units, lower residential space consumption per family unit, a predominance of younger (20-29) and older (50+) workers, lower income levels, and shorter commuting distances --, from a "suburban" lifestyle with the opposite characteristics. All these socio-economic factors thus tend to be related to one another through the tendency of "lifestyle" to vary with distance from the city centre. The problem this creates in empirical analysis is that, even in a multiple regression model, it becomes very difficult to separate the effect of any of these factors from the others. This suggests that our results regarding the influence of socio-economic factors on commuting should be interpreted with great caution.

Despite these problems, however, all equations of the job location model explained a higher proportion of the variation in commuting distance than did the residential location model. Contrary to our expectations, the model seems to provide a better explanation of the commuting behaviour of household heads than of non-heads, since the $\bar{R}^2$ is higher for heads, and the wage gradient variable, WG_i, which is central to job location theory, is significant only for household heads. This suggests that, in addition to being applicable, as expected, to the particular decision framework of non-heads of households, and to the new entrants to the labour market (e.g. married women, school-leavers), the job location model is also highly relevant to heads of households, in particular those who have inhabited a given area for many years and face one or more new job location choices.[59]

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59 This point was suggested by Prof. M.E. Beesley and Peter Kettle in their comments and suggestions on our earlier research - Gera and Kuhn (1977).

Section 5: An Overview of the Performance of the Two Models

In this section, we make some comments about the relative performance of the models tested, and their applicability to heads and non-heads of households.

Testing of the two models revealed that, while the job location model provides a better fit to the data in general, both job and residential location models are powerful tools in explaining the variation in mean commuting distance in the Toronto CMA. This suggests that both the residence and job location decisions of workers could be important determinants of journey-to-work distance, depending of course on their situation; though these decisions are not necessarily made simultaneously, neither the worker's job nor residence location can be viewed as fixed for all purposes. We, however, suspect that the job location model is applicable in more cases than the residential location model and thus, the most useful theoretical perspective from which to analyze the journey-to-work in urban Canada is one which sees the journey-to-work largely as a result of the worker's job location decision, given his residence site.[60]

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60 A similar observation was made in an earlier paper which studied the spatial pattern of commuting flows in the Toronto CMA (see, Gera, Betcherman and Paproski, 1978, pp. 88-118) when the importance of the concept of "intervening employment opportunities" between a (presumably given) residence site and prospective workplace was noted. Indeed, given the existence of relatively cheap and convenient transportation in Toronto, combined with the great importance of factors like social and physical neighbourhood characteristics in selecting a residence site, which we have demonstrated in yet another paper (Gera and Kuhn, 1978), this proposition seems not at all unlikely.

The main findings of the model testing regarding the determinants of journey-to-work distance are summarized below:

(i) In all cases, the most significant determinant of journey-to-work length was the degree of job or residence "choice" available, as embodied in the variables EP and RP respectively. The importance of the search for a job or residence of a given *type* (as this implies) is a very significant finding of this study.

(ii) Cross-sectional variation in transportation costs did not seem to play an important role in either of the two models.

(iii) The location-rent and wage gradients, as expected, had an important effect in the residence and job location decisions, respectively. The effect of the rent-gradient impact was confined to those working in or near the CBD, tending to discourage both heads and non-heads with central workplaces from living close to work. The effect of the wage gradient was operative only for household heads and seemed to be related to the pattern of urban growth:[61] residents of high-wage areas (particularly the high-growth western and north-western peripheral

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61 This is verified when we examine the urban patterns of earnings levels. Our examination yields two interesting conclusions. First, the high levels of earnings at or near the CBD (this is observed while comparing the average level of earnings paid in each zone in the Toronto CMA) confirms the theoretical expectations of Evans (1973) who maintained that such a differential would arise to compensate workers at the CBD for their higher rents and/or commuting costs. Secondly, the general trend for earnings to be higher in the western end of the CMA seems to relate to the generally faster growth of industry in that direction (See Gera, Betcherman, and Paproski, 1978, p. 9). It seems that the uneven pattern of metropolitan growth towards the west carries with it a hidden cost in terms of the higher wages paid by firms in the rapidly growing areas in order to attract workers, *and* in terms of the longer commuting distances travelled by workers living in low wage, slow growth areas. Moreover, we also note that there is a positive bias in the employment potential towards west of the CBD (the borough of Etobicoke) which provides support for a higher level of average earnings in that sector of the CMA.

areas of the CMA) tended to commute shorter distances to work than residents of low wage areas.[62]

(iv) Several socio-economic characteristics of the workers had a significant effect on journey-to-work distance, even when other factors were controlled for. The effect of these factors was particularly evident for the total sample (equation 1); in general they showed that older workers travelled shorter distances than younger workers, female less than males, and blue-collar workers less than white-collar workers.

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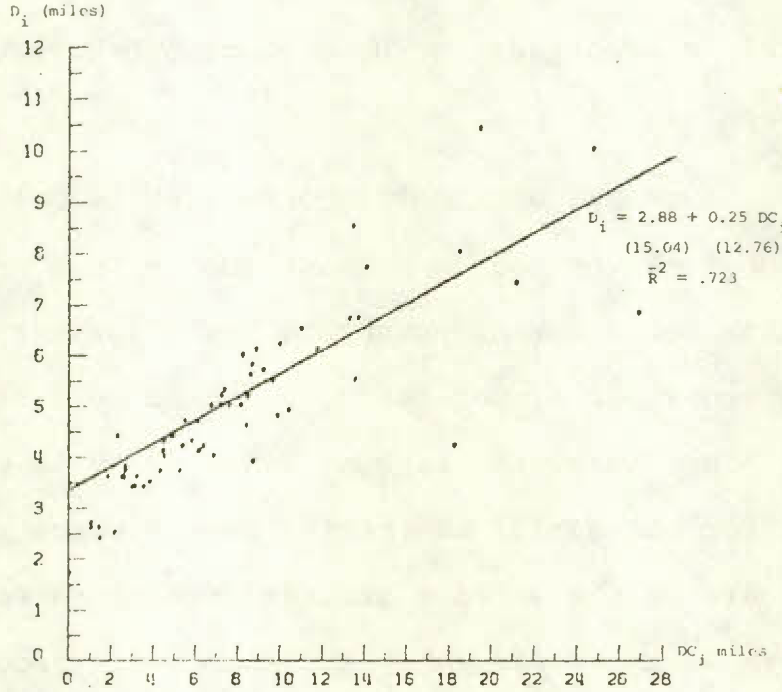
62 This observation is supported by examining the pattern of employment potential by zones in the Toronto CMA. The strong tendency of employment potential to decrease with distance from the centre of the city in the Toronto CMA explains the tendency for commuting distance at the zone of residence to increase to high levels in the peripheral areas (usually low wage areas except to the west of the CBD). This was noted in the Toronto CMA (see Gera, Betcherman, and Paproski, 1978, p. 133) and is reflected in Figure 3 below.

Figure 3

RELATIONSHIP BETWEEN MEAN COMMUTING DISTANCE AT THE PLACE OF RESIDENCE (D_i) AND RESIDENCE ZONE DISTANCE FROM THE CBD, (DC_i) TORONTO CMA, 1971



Note - t-values in parentheses

Source: Statistics Canada and estimates by the authors.

Considering the relative applicability of the models to the commuting behaviour of heads and non-heads of households, we note an unexpected result. Although it was expected that the commuting behaviour of household heads would be best explained by the residential location model and the commuting behaviour of non-heads by the job location model, it turned out that both models performed better for household heads. No appreciable difference is noted in the commuting behaviour of heads and non-heads of households in the residential location model. In the job location model, the main overall difference between the commuting behaviour of heads and non-heads seems to be the tendency for heads to be more responsive to the crucial wage gradient variable (WG) while the behaviour of non-heads is more responsive to their socio-economic characteristics. This suggests that, while the earnings-transportation cost tradeoff implied by the job location theory may be an important factor in the job location decisions of the household heads, these factors are not as important in the commuting behaviour of non-heads of households.

Thus, our analysis indicates that while both the residential and job location models are applicable to a great extent to the commuting behaviour of household heads (primary earners), the commuting behaviour of non-heads is not as well explained by these models. Certainly, the lack of sensitivity to wage differentials found for non-heads, and their lower average commuting distance indicate on the whole a greater preference for easy access relative to increased money earnings among secondary wage earners, but more theoretical and empirical work in this area is required. Moreover, the greater socio-economic heterogeneity of the non-heads group suggests that one single model is not appropriate for all members of this group, which includes both working mothers and teenage workers, for example. The important steps that might be taken in this direction include: a more precise delineation of the secondary wage earner category and perhaps its subdivision into more homogeneous subgroups; consideration of the labour force participation decision simultaneously with the journey-to-work decision; and consideration of the influence of varying social norms on the labour force participation of the married women.

In addition, several major changes to our theoretical models of the city are necessary if these are to be applicable to the present-day Canadian context. The main modification that seems to be necessary is an incorporation of the concept of *choice* as a crucial element in the residence and job location decisions, taking account simultaneously of the effect that diminished transportation costs have on urban structure and especially on the determinants of commuting behaviour. This concept may be incorporated into the economic theories of residence and job location to give them a new relevance.

Section 6: Practical Implications

The findings of this study suggest a number of important implications relevant to the future planning of metropolitan expansion and renewal, particularly in Canada. Of course, the general relevance of these findings depends on the extent to which certain basic characteristics of the Toronto CMA apply to other urban areas. For example, some conclusions based on a city the size of Toronto may not hold in smaller Canadian urban areas, and moreover, the topographical features of other large cities (Montreal and Vancouver in particular) might pose special problems of their own. Still, some of the overall trends and relationships identified by the models here are likely to apply to many Canadian metropolitan areas, given their many common features -- such as high car-ownership rates, a relatively young labour force, comparable income levels, etc. Thus, we hope that the implications identified here will be of interest to all those involved in urban planning in Canada. The implications can be summarized as follows:

(i) The fact that the commuting behaviour of secondary wage earners seems to be determined by a different set of factors from those influencing primary wage earners suggests that decisions regarding the location of new residential and employment opportunities should take into account the effect of this large and growing proportion of the labour force on travel demand. Although the relationships affecting the commuting distance of secondary earners do not fully and distinctly emerge from our model results, and further research is required, the apparently greater desire or need for accessibility by secondary wage earners should be an important consideration in future development decisions.

(ii) In the residential location model, the marginal savings in location-rents available at the work-zone (approximated by the reciprocal of its distance from the central business district), and the zone's overall proximity to residential opportunities (measured by the variable "residence potential") have important, but rather complex, implications for the possible effects of the location of new and relocation of existing employment opportunities within the CMA. It implies, on the one hand, that the location of more employment opportunities in the core will tend to increase commuting distances because of the significant effect of the location-rent gradient there. However, it also implies that the location of more employment in the outer fringe areas of the CMA, where residential options are spread out over a large area, will tend to increase commuting distances as well. In fact, as we noted earlier, the interaction of the location-rent and residential-potential variables seems to lead to a situation in Toronto where there is a U-shaped relationship between work-zone distance from the centre and commuting distance, with high commuting distances for CBD workers and even higher commuting distances for those with workplaces near the outer fringe of the CMA, while the work-trip distances for the intermediate areas between the core and the fringes are relatively shorter. Thus, the following tentative conclusions may be suggested:

- while movement of employment opportunities from the core to intermediate areas, where the location-rent gradient is less important but residence-potential is high, will likely have the effect of reducing commuting distances in Toronto, this argument cannot apply to the movement of employment to the most peripheral (fringe) areas of the CMA; and

- that the maintenance of employment-generating activity in and around the central business district may not have *as strong* an impact on increasing commuting distances in the Toronto CMA as the movement of these activities to outer peripheral areas where the degree of residential *choice* is highly dispersed.

(iii) The observed responsiveness of the workers to the relative level of earnings received in the home zone and the zone's overall proximity to job opportunities (in the job location model) may have some interesting planning implications for the Toronto CMA. The obvious implication seems to be that the growth of the residential population in areas of low relative wages and low employment potential will tend to increase the length of the work-trip. Considering these two aspects (relative wages and employment potential) separately, we can tentatively conclude that:

- the continuing movement of the residential population of the CMA into more and more peripheral and, hence, low employment-potential areas, as the city grows seems to have an upward impact, as might be expected, on journey-to-work distance. This tendency of commuting distance to increase with residential decentralization may be seen as one of the costs of continued urban growth in large metropolitan areas.

- the negative relationship between earnings in the home zone and commuting distance has an interesting interpretation with respect to the direction of present and future growth in the Toronto CMA. While the results of our study directly suggest that the encouragement of more residential growth in low-wage (eastern) areas will tend to increase commuting distances, the encouragement of more employment growth in high-wage (western) areas may also tend to increase commuting distances, because of the "imbalance" in wage opportunities established across the CMA. Indeed, the tendency for residents of the slower-growing, lower-employment-potential, low-wage eastern parts of the CMA (much of Scarborough and zone 63 - see map 1) to commute, on the average, longer distances to work than residents of the faster-growing, higher-employment-potential, high-wage western areas (Etobicoke, Mississauga), suggests that there is a hidden cost to the uneven growth of the CMA in different directions. This cost is borne both by firms in high growth areas in terms of paying higher wages in order to attract workers, and by residents of the low-growth areas in terms of higher commuting distances or accepting lower wages in nearby zones. Thus future development decisions might consider the proposition of encouraging industrial growth in areas other than western parts of the CMA. While the marginal costs of job commuting may not be perceived as critical factors in the individual's or firm's locational decision-making they are by no means fixed or entirely internalized (see, v below). As energy and transportation infrastructure become relatively more expensive, the hidden cost of uneven metropolitan growth in one particular direction may in fact be more costly, to individuals, firms and the community as a whole, than it may appear to be in the short-term. This suggests that concern be focussed on effectively achieving a closer correspondence between residences and jobs.

(iv) The importance of the "choice" factor in both the residence and job location decisions has particular relevance for the concept of "satellite communities". Given the existing cost and availability of urban transportation, workers living or working in the suburbs seem to be willing to travel very long distances to and from work to increase their degree of job and residence choice. Thus, urban planning strategies to reduce the amount of journey-to-work travel by establishing "self-sufficient" suburban communities in terms of both residential and job opportunities should consider maintaining a very close match of job characteristics and residential attributes to ensure the relative "self-sufficiency" of such satellite communities; simple maintenance of a reasonable residence-job ratio is not a sufficient criterion for achieving such harmony.

(v) The fact that the effects of transportation costs seem to be completely overshadowed by considerations of "choice" in the residence and job location decisions of individuals highlights an interesting problem of social options in urban areas. For example, if the social costs of transportation (which include pollution, noise, accidents, etc.) exceed its private costs by a significant amount, the models here could be taken to imply that individuals are opting for a greater-than-optimal amount of (cheap) transportation in order to obtain more residence and job *choice*. On the other hand, one could interpret choice itself as one of the long-run external benefits of cheap transportation, which led to the development of large, integrated urban areas offering a much greater variety of goods, services, residential environments, and jobs. Thus, although our models say nothing about the optimality of the present situation, they do suggest that there is an important private and public tradeoff to be made between the amount of choice exercised and the amount of transportation undertaken. This relationship should be an important consideration in decisions affecting the cost and availability of urban transportation, its well-known external costs being weighed against its external benefits in terms of *choice*.

(vi) The relationship between journey-to-work distance and the socio-economic characteristics of the commuter is not that impressive given the overriding impact of residence and job *choices*. However, the effects of sex and of age on commuting distance, observed in the models, suggest that these two factors are particularly related to the worker's need for accessibility to work. Female workers in particular are largely reliant upon jobs near their homes. As workers age, changes take place in workforce participation, in the demand for different types of jobs and particularly, in their demand for accessibility. Thus, the accessibility needs of working women (especially housewives) and of older workers should be noted and considered in the location of housing and employment opportunities.

Many of the basic implications that emerge from the testing of the residential and job location models in the Toronto CMA, although tentative, might be considered indicative. A further area of interest concerns an explicit incorporation of the element of *choice* into the modelling of residential location and job location. It is suggested that the models described in this paper have relevance to the process of urban decision-making.

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