Factors for the Study of Long-term Impacts of Telecommuting and Intelligent Transportation Systems on Residential and Business Location Choice

Mohammad R. Tayyaran
Ph.D. Candidate

A.M. Khan
Professor

Dept. of Civil & Environmental Engineering
Carleton University
3432 C.J. Mackenzie Building
1125 Colonel By Drive
Ottawa, Canada K1S 5B6

1. INTRODUCTION

Early cities were small and highly centralized around the urban core. This was due to the prevailing transportation technology (i.e., mainly walking, horse, horsecar) at the time. However, the advent of electric street cars in the late nineteenth century allowed urban areas to expand along street car lines radiating from the central city (Meyer & Miller, 1984; Young, 1990). The second major technological innovation in 1920s, the automobile, allowed even more freedom for urban growth, thus resulting in urban sprawl. Urban growth has occurred in the form of low density bedroom suburbs located at the urban fringe, and in some cases even lower density developments emanating from these suburbs (Hanson, 1992; Meyer & Miller, 1984).

Today, we are faced with two new transportation and communications technologies: Intelligent Transportation Systems (ITS) and telecommuting. According to ITS Canada "ITS technologies include micro-electronics, mobile communications, computer informatics and other advanced technologies to improve mobility, safety and security, and productivity in the transportation sector, in association with other measures to reduce energy consumption, improve air quality and enhance transportation accessibility."

The second technological phenomenon is telecommuting. It involves the use of communications technologies to partially or completely replace daily trips to and from workplace (Mokhtarian, 1992). As defined by Nilles (1991), telecommuting is a subset of teleworking which is the substitution of telecommunication technologies for work related travel.

Considering the relationship between land use and transportation, the question is: What will be the effects of new technologies of ITS and telecommuting on urban development pattern, which in turn has effects on travel demand pattern? These two new technological innovations will have some short-and long-term implications for travel behavior and land use. As discussed in the following subsections, the long-term effects of ITS and telecommuting are subject to uncertainty. Different studies have advanced different hypotheses about their impacts on the resulting land use patterns and in particular on both residential and business location decisions.

It is the purpose of this paper to provide an insight into the effects of ITS and telecommuting on residential as well as business location behavior. Specifically, this paper has two objectives. First, is to describe the state of knowledge on the relationship between technologies of ITS and telecommuting and urban development patterns. Second, to advance models of residential and business location in the light of ITS and telecommuting.

1.1. Intelligent Transportation Systems (ITS)

Although ITS developments are advancing rapidly in North America, similar technologies have been demonstrated in Europe (e.g., PROMETHEUS in Germany) and Japan (i.e., AMTICS) to be very effective in enhancing transportation systems.

There is no doubt that ITS technologies, due to their capability to improve transportation system operations, are likely to have implications for both individuals and the society as a whole. These can be classified into short-term and long-term effects. As for the short term effects, pilot projects in the U.S. have shown very little ambiguity in terms of the resulting benefits (Transportation Research Board, 1993; GAO, 1991). Benefits have resulted especially in the area of congestion reduction. Most of these projects have shown that economic, safety and air quality benefits are also possible.

The long-term effects of ITS are, however, not so clear as are the short-term effects. ITS is different from other transportation system improvements in that it is promising to enhance capacity and efficiency without any physical expansion (or very little, if any) to the existing system.

The historical development of cities has served as evidence that, in the long-run, transportation improvements have caused urban areas to expand in the direction of these improvements. In the case of ITS, it has been speculated that such transportation improvements may cause new land developments further away from existing ones. ITS is capable of reducing travel times between an origin and a destination (e.g., through enhanced traffic control) as well as increasing the travel time reliabilities by means of providing real-time information to motorists. This capability may encourage individuals to move their residential location further away where housing is more spacious and less costly than in central city, without having to spend more time traveling. This may contribute to the development of outlying communities.

These issues have been dealt with and discussed only qualitatively in the literature mainly due to lack of data (Shladover, 1993; Ostria and Lawrence, 1994). Additionally, Mokhtarian (1993) believes that the contribution of ITS to decentralization might be much larger than that of telecommuting because ITS will most likely ultimately be available to everyone all the time. These observations imply a definite research need in this area.

1.2. Telecommuting

While the concept of telecommuting has been around as early as 1950s, it was never pursued seriously because of the technology limitations and the prevailing lifestyle at that time. However, with the rapid development of advanced computer and telecommunication technologies during the last decade, and the increasing social cost of transportation and changes in individuals' lifestyles, telecommuting is starting to gain more and more acceptance in the U.S. and elsewhere as a potential means for alleviating traffic congestion, energy consumption and air pollution (Bernardino et al, 1993). One study forecasts the number of telecommuters in the U.S. between 7.5 to 15 millions by the year 2002 (Hopkins et al, 1994), while another one estimates this number to be 24 and 50 millions for the years 2000 and 2010, respectively (Telecommuting Research Institute, 1991). In Canada, a recent Gallop poll estimated that approximately 2.2 million Canadians work at home some of the time, whereas the 1991 Census estimated this number to be around 1.1 million (Gurstein, 1994). The existence of such a wide range of estimates is attributed to disparate definitions of working at home.

As is the case with ITS, a distinction should be made between short- and long-term effects of telecommuting. In the short-run, it is expected that telecommuting will result in a reduction in the number of peak-hour trips due to the reduction of commutes. As an example, Regional Municipality of Ottawa-Carleton in Ontario, Canada has included telework as a Transportation Demand Management (TDM) measure in its transportation master plan. They expect that this measure alone would reduce peak hour work trips by 7% (Institute of Transportation Engineers [ITE], 1996). Empirical evidence from several studies has shown some positive transportation impacts of telecommuting including reduction in vehicle kilometres of travel (VKT), and fuel consumption and emissions (Irwin, 1994; Weiner, 1994; Pendyala et al, 1991; Hamer et al, 1991 & 1992). Telecommuting may also change other travel factors such as time of day, mode of travel, and destination (Mokhtarian, 1992).

Long-term effects due to adoption of telecommuting are also expected. Level of automobile ownership may be reduced. Of great importance, is the land use impact of telecommuting. The evidence to date regarding the impacts of telecommuting on residential location is not conclusive. One view suggests that telecommunications would lead to more dispersed locational patterns (Lund and Mokhtarian, 1994; Hopkins et al, 1994), whereas another viewpoint is that telecommunications may not affect the existing locational patterns significantly (Nijkamp and Salomon, 1989; Nilles, 1991; Mokhtarian, 1993). Moreover, Blais (1994), Webber, and Manderville (cited in Young, 1990) have supported the suggestion that telecommuting is neutral, meaning that it has no particular effect on urban development pattern.

A telework symposium was recently held in Toronto to promote awareness of and education about telecommuting. There were mixed feelings about the spatial impacts of telework in that they ranged from no or minimal relocation impacts to high relocation impacts in terms of moving towards suburban and rural areas. In fact, at this symposium, results of a national study funded by Canada Mortgage and Housing Corporation (CMHC) were presented that aimed at providing some insight into factors that affect telework and home-based employment. Some of their important findings as they relate to this paper were as follows (Gurstein, 1994):

- 80% of respondents were very satisfied with working at home;
- The majority of teleworkers lived in single-family detached homes in suburban areas;
- About 20% of teleworkers had moved or were planning to move outside the city.

However, no model was developed to analyze the acquired information.

In the long run, telecommuting may also affect business location decisions. If and when an organization makes telecommuting available to its employees, it can accrue significant cost savings by reduced requirements for office and parking space. Other benefits may also be obtained by decreasing absenteeism and sick leave (Bernardino et al, 1993). Considering that land cost is an important factor in business location decisions, this means that an organization currently located in the Central Business District (CBD) can relocate to another place whether in the same city or to a suburb where office space is less costly, and/or setup new small branch office(s) close to its employees' residences in distant suburbia. In any case, it is reasonable to speculate that telecommunications in general, and teleworking in particular may contribute to further decentralization of urban areas and the growth of second tier or third tier satellites. This view is supported by Irwin (1994) and Young (1990). As is the case with residential location, there has been no research to date to study quantitatively such impacts of telecommuting on business location decisions.

Since the discussion is on the long term effects of ITS and telecommuting on residential and business land uses, it is also useful to have a literature review of the studies of residential and business location. This review is presented below.

2. LOCATION THEORY

Location theory generally deals with the issue of how various land uses compete for space in a region (Steiner, 1994). It has its roots in as early as the 19th century when Ricardo (cited in Deakin, 1991) observed that the primary inputs of production are land, labor and capital and that location of land determines, in part, its use. Since then many researchers have attempted to develop mathematical models for different land uses including residential and commercial use. The following subsections explains such endeavors.

2.1. Residential Location Choice

Residential location theories can be divided into three broad categories: hedonic pricing models, urban economic models, and discrete choice models. The first group of models focuses on factors that affect the housing value through multiple regression of key attributes of housing and neighborhoods (Steiner, 1994). In terms of second category, one of the most prominent theories of urban growth is the bid rent theory introduced by Alonso (1964) which focuses on economic factors in explaining the urban spatial structure. This theory is based on marginal utility theory and had other followers like Muth (1969) and Goldberg & Chinloy(1984). Although very popular, this theory has some theoretical and empirical shortcomings. One major restriction of this theory is that it is based on the concept of a monocentric city with a (CBD) in the center and housing units arranged around it (Anas, 1982). Another problem is that it does not consider the leisure time budget which is a major factor in residential location choice. The problems with the deterministic approach made urban planers and economists to depart from it and develop other formulations, one of them being development of discrete choice models in the context of random utility theory, of which the logit and probit models are the most popular ones. The probabilistic concept of this approach enables us to take into account explicitly the variations in taste and preference of individuals in choosing their housing location as well as socio-economic differences within each population group.

The discrete choice models have had extensive transportation applications particularly for the choice of travel modes (e.g., Domencich & McFadden, 1975; Richards & Ben-Akiva, 1975; Ben-Akiva, 1973). However, due to its nature, the discrete choice analysis can be and has been applied to numerous fields including urban planning, telecommunications, operations research, market research and public policy. More will be said about stochastic disaggregate models later in the paper.

Residential choice models have been used for almost two decades. These models focus on trade-offs among various factors which influence residential choice. Most of these studies developed logit models in one form or another. Some developed simple multinomial logit (MNL) model (Pollakowski, 1982; Friedman, 1981; Quigley, 1976) while others developed joint logit model of residential location and mode to work (Lerman, 1976; Anas, 1982; Horowitz, 1986) and nested logit model (Weisbrod et al, 1980; Quigley, 1985; Ben-Akiva & dePalma, 1986; Kim, 1991) to explain households' residential location decisions. Most of these studies have included in their utility model, in addition to housing price and transportation accessibility measures, socio-economic factors such as age, income, family size, auto ownership level, etc., and level of public services such as property tax rate, per pupil school expenditures, etc. A list of various attributes influencing the housing choice is provided by Hunt et al (1994) along with their relevant source references.

It is important to note that although transportation variables (e.g., time and cost) do matter in the residential location decisions, recent models have shown that these are no more critical to location decisions than other factors such as housing type, neighborhood quality as well as life-cycle of the households (Deakin, 1991; Lerman, 1976; Weisbrod, 1978; Weisbrod et al, 1980; Giuliano, 1995).

2.2. Business Location Choice

Theories of urban employment location may be broadly divided into two categories: deterministic equilibrium models and behavioral models (Hansen, 1987). The traditional Alonso-Muth formulation, of course, falls into the first set. As mentioned earlier, these models are based on monocentricity assumption. Further, they assume that urban structure is given, and firms have profit-maximization objectives. Therefore, their emphasis is on cost reduction—particularly transportation costs- and because of their need for face-to-face contact with others, they are willing to outbid others in order to get a location in the center (Shukla & Waddell, 1991; Steiner, 1994). The other class of models—the behavioral approach to business location—was a result of unrealistic assumptions in the former models including: monocentricity, profit-maximization, perfect information, and instantaneous response to changes in the spatial variation in factor prices (Hansen, 1987). The major advantage of these models is that they can incorporate behavioral insights and are easier to relate to operationalization than the more abstract former set of models (Shukla & Waddell, 1991). These models are based on the utility maximization axiom over a set of discrete alternatives. However, the discrete choice analysis for business location choice has not been as widely used as it has been for the study of residential choice. Some studies developed simple MNL models (Carlton, 1979, 1983; Shukla & Waddell, 1991) while others developed a more generalized nested logit model (Hayashi et al, 1986, Hansen, 1987) to explain various industries location decisions. Most of these studies have included in their utility models factors such as land cost and availability, transportation accessibility to consumers and suppliers, labor availability, wages, taxes, and measures of agglomeration economies and quality of life.

3. STATED PREFERENCE VS. REVEALED PREFERENCE APPROACH

All the literature items reviewed so far, used the *revealed preference* approach in studying the housing as well as business location behavior. Choice models based on revealed (or observed) behavior are calibrated to actual data, and therefore they have a high degree of reliability. Revealed Preference (RP) data, however, suffer from a number of perspectives (Kroes and Sheldon, 1988):

- correlation exists among some of the attributes (eg., time and cost), and thereby trade-offs among these attributes may not be clearly observable;
- there is a limited range of attributes;
- some choice alternatives, characteristics, and/or services may not exist.

From the viewpoint of this paper, the last-mentioned shortcoming of RP data has a strong bearing on this paper. Telecommuting and ITS are innovative technologies whose effects on residential and business location are not conclusive, on the basis of what has been studied so far, simply because there are not enough *observed data* for them. Therefore to investigate their impacts on the residential and business choice, one must consider another refined method. *Stated preference* (SP) approach, is a technique that was developed to overcome the above problems of RP data. In this method, individuals are presented with hypothetical alternatives and asked to indicate their preferences towards the choices offered (Hunt et al, 1994; Pearmain et al, 1991). In this technique, the researcher has a complete control over the factors that influence the choice. Therefore, SP models can be designed to reduce or eliminate the interdependency among attributes, can provide respondents with broader ranges of choice attributes, and can include policies and alternatives that are completely new (Louviere et al, 1981).

3.1. Housing Location Behavior Using SP Techniques

The above-mentioned weaknesses associated with RP data encouraged researchers to divert to conjoint analysis in studies of housing preferences, in one form or the other. These studies successfully provided insight into the influences of factors affecting residential choice behavior of individuals (Louviere, 1979; Timmermans, 1984; Joseph et al, 1989; Hunt et al, 1994).

Although a powerful method, the SP data suffer from a serious backdrop. The principal weakness is the fact that respondents are *stating* what they would do given the *hypothetical choices*, which implies that in reality they may not necessarily do what they say. Therefore, the reliability of SP data is uncertain. This is a problem which is not very serious with RP data because those models are calibrated against actual behavior not the intended ones. The reliability of SP data is manifested in two different ways: “validity” and “stability” (Ben-Akiva & Morikawa, 1990a). Lack of validity indicates a discrepancy between actual and stated behavior and it relates to a bias in SP data.. Lack of stability corresponds to the magnitude of random error or noise in the SP data and it often depends on the quality of survey and experimental design (Ben-Akiva & Morikawa, 1990a). Therefore, combining RP and SP data is an appealing way to overcome the shortcomings of each data type and to take advantage of their strengths. As such, RP and SP data complement each other. The *mixed estimation* has some statistical issues associated with it and recent developments in combined analysis of RP and SP data have addressed most of them (Ben-Akiva & Morikawa, 1990a,b; Morikawa, 1994; Pearmain et al, 1991; Bradley & Kroes, 1990). More about the mixed estimation method will be said later.

3.2. Business Location Behavior Using SP Techniques

So far, to our knowledge no study has attempted to use SP and/or combined RP and SP techniques for analyzing business location decisions. Therefore, this study will make a major contribution in this area of work. In fact, as is the case with the residential location behavior, a combined RP and SP logit or probit analysis can be carried out for the business location choice.

4. A RESEARCH FRAMEWORK

The literature review revealed that there is mixed evidence regarding the impacts of ITS and telecommuting on urban development patterns, thereby making it worthwhile to probe this area of work. None of the previous studies of residential and business location choice have investigated such impacts of ITS and telecommuting. However, the important point is to figure out how the attributes of ITS and telecommuting will be introduced and measured in this analysis. To answer this, one should find out in what ways these technologies will affect people. In other words, how individuals will *perceive* these technologies. For the ITS case, the most prominent characteristics, as perceived by users, could be:

- shorter travel times for motorists and transit users.
- more reliable (or less variable) travel times. Because of the real-time information provided by ITS (as well as a historic database constructed in this way over time which will be fed back to the system), commuters and other travelers will be much more certain about the roadway and traffic conditions ahead of them. Reduction in travel time variability might be the most important aspect of ITS from the user point of view. This variability will have two dimensions: magnitude and frequency (e.g. 5 minutes a day, 10 minutes a week, etc.) (Senna, 1994).

For telecommuting, the relevant characteristic will be savings in travel time and money due to less need for daily work trips plus other social conveniences (e.g., comfort of being at home, flexible hours, control over work).

In terms of business location, the relevant telecommuting characteristics will be cost savings due to less need for office and parking space for organizations.

4.1. Methodological Considerations

To study the effects of ITS and telecommuting on individuals' housing and business location decisions, stated preference approach (i.e., conjoint analysis) within the random utility theory can be adopted. The residential model will provide information regarding the trade-offs among various factors that affect housing choice behavior, and in particular, the relative weights of ITS and telecommuting in the decision process. The business model will serve the same purpose for the firms' location choice behavior.

Combined RP and SP logit analysis can be used to estimate the parameters of the utility function through attitudinal survey of people which is explained briefly in the next section. The combined estimation procedure is also explained. The research framework is shown in Figure 1.

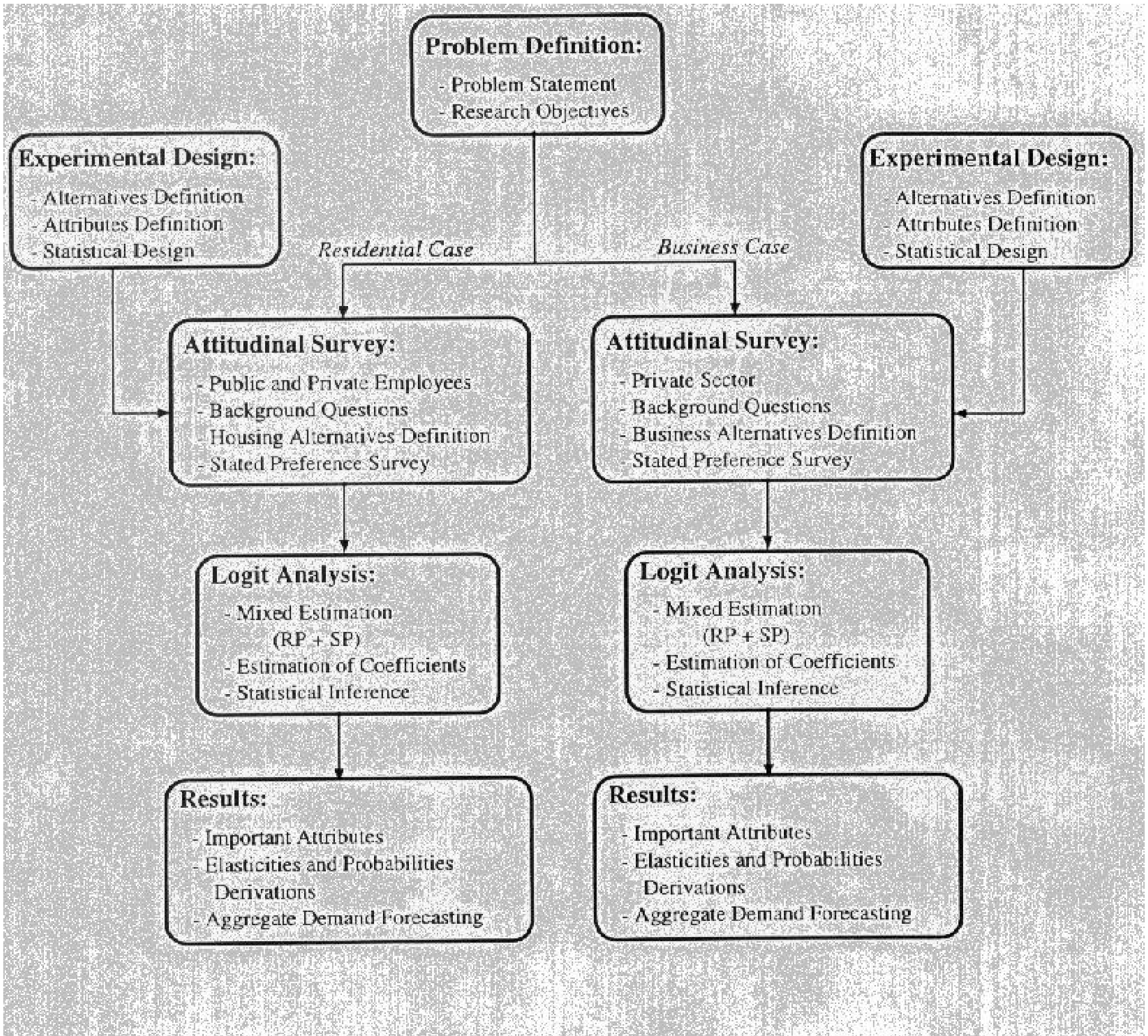

Fig. 1. Research Framework

As such, the original contributions of this research study in expanding the present state of knowledge are as follows:

- Introducing telecommuting and ITS measures in the study of residential location choice;
- Introducing telecommuting measures in the study of business location choice;
- Use of combined RP and SP data in residential location choice; and
- Use of combined RP and SP data in business location choice.

5. SURVEY DESIGN

The intent of this research is to find out whether adopting telecommuting by individuals and deployment of ITS will result in any change in their housing location decision. Similarly, we want to know if adoption of telecommuting by firms will affect their location decision. To do so, one has to carry out a case study by means of an attitudinal survey. The Regional Municipality of Ottawa-Carleton (RMOC), Ontario, Canada is chosen for this purpose. Based on the Official Plan of the RMOC (1988) any future growth in the region is to be accommodated in three satellite cities namely Kanata, Nepean, and Orleans, located in some distance in the west, south, and east of Ottawa, respectively. Figure 2 shows the study area. Moreover, it is highly likely that any growth beyond those predicted by the official plan will be located in second-tier satellite cities in the longer term. In other words, the plan does not permit sprawl to happen in the future; rather any growth in population, housing, and business will have to happen in the satellite nodes located on the well-defined transportation axes. Thus, for the purpose of this research, three location alternatives are defined as follows (these locational alternatives are applicable for both the residential and the business location analysis):

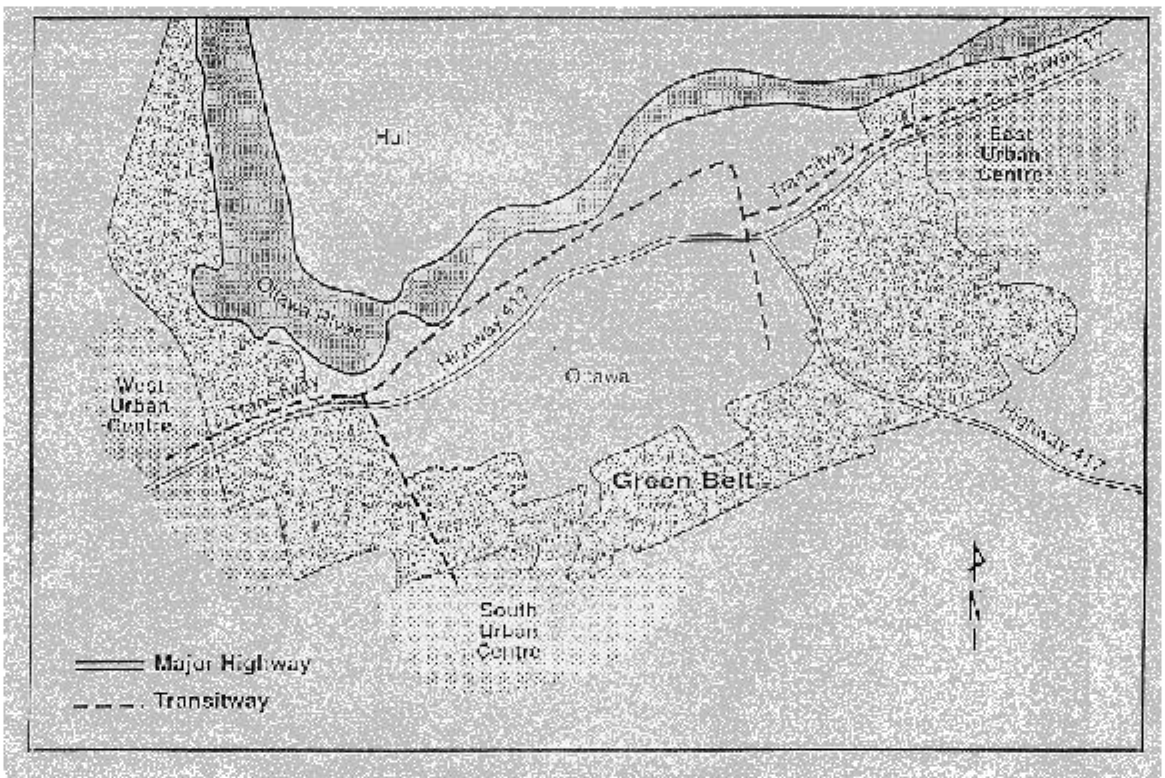

Fig. 2. The Study Area within the RMOC, Ontario, Canada

Alt. A - Central area of the region inside the Green Belt consisting of cities of Ottawa, Vanier, Nepean, Gloucester, Village of Rockcliffe, and City of Hull.

Alt. B - First-tier satellite nodes including cities of Kanata, Aylmer, Gatineau, and Townships of Cumberland (i.e., Orleans), Barrhaven, and Chelsea.

Alt. C - Second-tier satellite nodes such as Buckingham and Rockland in east, Rideau and Osgoode in south, West Carleton and Goulborn in west, and Clarence and Val-des-mont in north.

Figure 3 shows a schematic diagram of location of these alternatives in the region. Two survey questionnaires are designed, one for the household residential location and another for the business location choice. The residential choice survey consists of two major parts. Part 1 is the revealed preference one. It asks questions from employees in the region about their residential location such as their housing cost, number of bedrooms, their travel mode to work, their commute time and cost to work, as well as some socio-demographic information. Part 2 is the stated preference one. In this part the respondent is presented with a number of hypothetical choice situations. In each choice situation, alternatives A, B, and C are defined in terms of the combination of factors (or attributes). These factors can include: housing cost, number of bedrooms, number of telecommuting days per week, amount and frequency of travel time variability to work, etc. Then, for each choice situation, the respondent is asked to state which alternative s/he would most probably choose as the place to live in. The business location survey also consists of two major parts: the revealed preference and stated preference but in the context of firm location choice. That is, in the first part, firms are posed with questions about their current location, size of their organization, lease costs, etc. In the second part, the attributes presented to them can be wage rate, land cost, distance to nearest freeway, availability and degree of intensity of a telecommute program. In this case, the alternatives available to them are the same as those in the residential case. Then, for each hypothetical choice situation, the firm is to select the most preferred alternative based on the combination of above-mentioned factors. The experimental design in both cases, of course, will be *orthogonal*. That is, the combinations of these factors in the experiment are so defined as to ensure that they are varied independently (i.e., completely uncorrelated) from one another (Kroes & Sheldon, 1988).

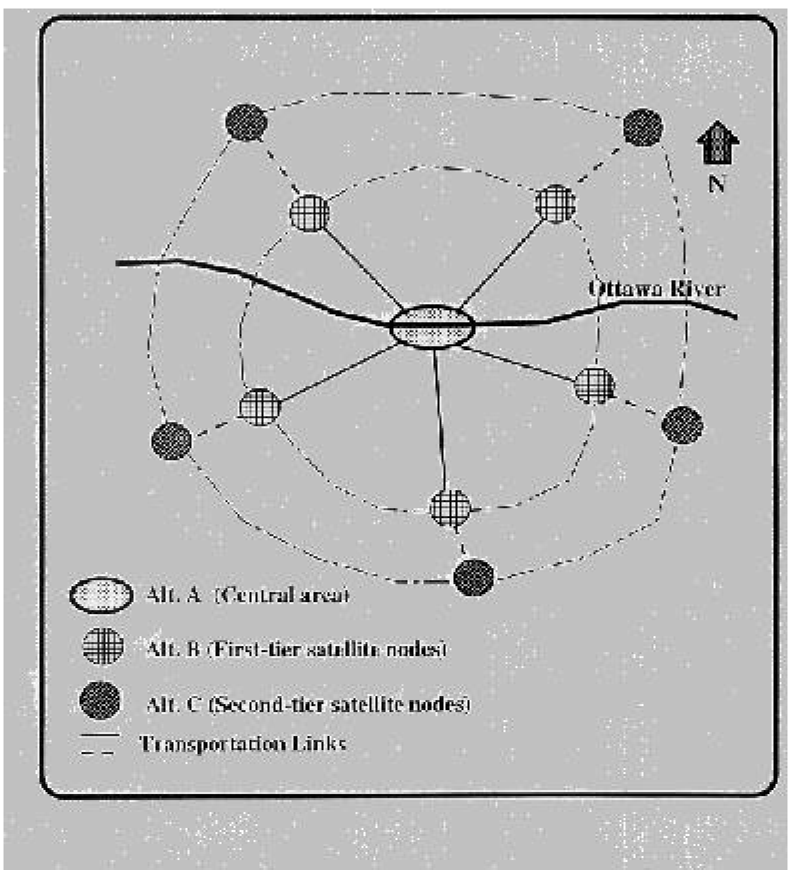

Fig. 3. Schematic Diagram of Housing and Business Location Alternatives

6. ANALYSIS OF SURVEY DATA

Having administered the survey, the data are to be analyzed and modeled within the utility maximization theory framework. The following sub-sections explain the model estimation procedure. It goes without saying that two different models are constructed, one for the residential and another for the business location choice.

6.1. Combining RP and SP data

It was mentioned earlier that SP and RP data have complimentary characteristics. Joint estimation of SP and RP data can provide estimates of parameters that are efficient and are corrected for bias of SP data. It also provides estimation of trade-offs among attributes and the effects of new services that are not identifiable from RP data (Morikawa, 1994). The theoretical framework for integrating RP and SP data was first developed by Morikawa (1989) and Ben-Akiva and Morikawa (1990a,b) which is based on utility maximization theory. This methodology is well suited for this research as well. To explain briefly, assume there are two different data generating processes: the RP model that represents actual choice, and the SP model that represents stated intentions. Then the utility expressions are defined as follows (Ben-Akiva & Morikawa, 1990a):

RP model:

$$U_i^{RP} = ß'x^{RP} + a'y^{RP} + e \quad (1)$$
$$= V_i^{RP} + e$$

SP model:

$$U_i^{SP} = ß'x^{SP} + ?'z^{SP} + v \quad (2)$$
$$= V_i^{SP} + v$$

$$Var(e) = \mu^2.Var(v) \quad (3)$$

where:

U_i= utility of alternative I (to individual m)
V_i= systematic component of U_i
x^{RP}, x^{SP}= a vector of observed variables common to RP and SP data
y^{RP}, z^{SP}= vectors of observed variables specific to one data type or the other
a,ß,?= vector of unknown parameters
e,v= random error components associated with RP and SP data configurations, respectively
μ= the scaling parameter.

Since the effects of unobserved factors may well be different between revealed and stated preferences, there is no reason to believe that e and v have identical distributions (although one may assume that they are independently distributed with zero mean). Introduction of scale parameter, μ, reflects the fact that the level of noise between the two data types (which is represented by their variances, e and v) are different (Ben-Akiva & Morikawa, 1990a; Hensher, 1994). Moreover, there are two fundamental assumptions implied by above equations. First, existence of variables x with coefficient vector ß in RP and SP models indicates that the trade-off relationship among major attributes is the same in both actual behavior and SP tasks. Secondly, it is assumed that RP and SP data are statistically independent. To quote Morikawa (1994):

> "...it is assumed that the random component of the utility of an alternative of an individual in the SP model is independently distributed from that of any alternative for the same individual in the RP model."

By introducing the scale factor µ, e and µv are identically and independently distributed (iid) not only within each type of data, but also across them, thus enabling one to combine the two data types and jointly estimate them. In this case, the SP model of Eq. (2), for the purpose of estimation, will be multiplied by µ:

$$\mu U_i^{SP} = \mu ß' x^{SP} + \mu ?' z + \mu v \quad (4)$$

6.2. Estimation Method

Unknown parameters a,ß,?, and µ can be estimated either by (a) joint maximum likelihood (MLE), using RP and SP data simultaneously, or (b) sequential MLE, using RP and SP data in sequence (Ben-Akiva & Morikawa, 1990a). Estimators obtained by either method are consistent. Joint estimation method produces more efficient estimators than the sequential method but requires programming the joint likelihood function in a general MLE program, whereas one can use an ordinary logit or probit estimation software in the sequential method.

6.3. Expected Results

The estimated coefficients of the models have several major uses:

1) They will reveal if telecommuting and ITS measures, among other factors, have any influence on the location choice decision of households or businesses.

2) They can be converted to either probability derivations or elasticities, which reflect the relative sensitivity of household (or firm, in the case of business model) choice probabilities to changes in each independent variable in the model (Weisbrod, 1978). This is of major interest to the urban planners, since this information indicates which variables have the most impact on individual's locational choice and thereby the most effective policies can be adopted accordingly to encourage (or discourage) the direction of the households' (or firms') movements.

3) They can be used to forecast *aggregate demand* for residential and business land uses for the three locational alternatives in this study. This can be accomplished by several means such as "average individual", "classification", or "sample enumeration" method (Ben-Akiva & Lerman, 1985). As such, these models can predict the number of households (or business firms) in each region or zone.

7. CONCLUDING REMARKS

The acceptance and adoption of telecommuting is increasing rapidly and ITS is gradually finding its way into the market. One major question is whether in the long run these technological innovations would influence urban development pattern in the same way as previous technologies like railroad and automobile did; that is, a trend toward more sub-urbanization and second- and third-tier satellite nodes. This paper is intended to provide answers to this question. The methodology defined here is the best possible since these technologies have not been in place for a long time and consequently there are not enough observed data on their impacts.

The study described here has a great potential in providing more insight into the impacts of ITS and telecommuting on the location patterns of households and businesses as well as predicting the effects of public policies on these location patterns. Therefore, the results should be of interest to transportation and urban planners as well as developers, policy makers and other researchers.

REFERENCES

Alonso, W. (1964). *Location and Land use: Toward a General Theory of Land Rents.* Cambridge, Mass.: Harvard University.

Anas, A. (1982). *Residential Location Markets and Urban Transportation.* New York: Academic Press, Inc.

Ben-Akiva, M. (1973). *Structure of Passenger Travel Demand Models.* Ph.D. Dissertation, Department of Civil Engineering, MIT, Cambridge, Mass.

Ben-Akiva, M., & de Palma, A. (1986). Analysis of a dynamic residential location choice model with transaction costs. *Journal of Regional Science,* 26, 321-341.

Ben-Akiva, M., & Lerman, S.R. (1985). *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge: MIT Press.

Ben-Akiva, M. & Morikawa, T. (1990a). Estimation of Travel demand models from multiple data sources. In: M. Koshi (ed), *Transportation and Traffic Theory (Proceedings of the 11th ISTTT) (pp.461-476),* New York: Elsevier Science Publishing Co., Inc.

Ben-Akiva, M. & Morikawa, T. (1990b). Estimation of switching models from revealed preferences and stated intentions. *Transportation Research A,* 24A, 485-495.

Bernardino, A., Ben-Akiva, M. & Salomon, I. (1993). Stated preference approach to modelling the adoption of telecommuting. *Transportation Research Record 1413,* Washington, DC: TRB, National Research Council.

Blais, P. (1994). Shaping communities of tomorrow. *Proceedings of Telework '94 Symposium: The evolution of a New Culture* (pp. 192-199), Toronto, Canada.

Bradley, M.A., & Kroes, E.P. (1990). Forecasting issues in stated preference survey research. *Paper for the 3rd International Conference on Survey Methods in Transportation,* Washington, D.C.

Carlton, D.W. (1979). Why new firms locate where they do: An econometric model. In: W. Wheaton (ed.), *Interregional*

Movements and Regional Growth (pp. 13-50), Washington D.C.: The Urban Institute.

Carlton, D.W. (1983). The location and employment choices of new firms: An econometric model with discrete and continuous endogenous variables. *The Review of Economics and Statistics,* Vol. LXV, 440-449.

Deakin, E.A. (1991). Jobs, housing, and transportation: Theory and evidence of interaction between land use and transportation. *Transportation, Urban Form and the Environment, Special Report 231.* Washington, DC: TRB, National Research Council.

Domencich, T.A., & McFadden, D. (1975). *Urban Travel Demand- A Behavioral Analysis.* Amsterdam: North-Holland Publishing Company.

Friedman, J. (1981). A conditional logit model of the role of local public services in residential choice. *Urban Studies,* 18, 347-358.

General Accounting Office (1991). *Smart Highways: An Assessment of their Potential to Improve Travel.* Report GAO/PEMD-91-18.

Giuliano, G. (1995). The weakening transportation-land use connection. *Access no. 6.* California: University of California Transportation Center.

Goldberg, M. & Chinloy, P. (1984). *Urban Land Economics.* New York: John Wiley & Sons, Inc.

Gurstein, P. (1994). Housing and Urban Design. *Proceedings of Telework '94 Symposium: The evolution of a New Culture* (pp. 157-170), Toronto, Canada.

Hamer, R., Kroes, E., & Van Ooststroom, H. (1991). Teleworking in the Netherlands: An evaluation of changes in travel behavior. *Transportation,* 18, 365-382.

Hamer, R., Kroes, E., Van Ooststroom, H. & Kockelkoren, M. (1992). Teleworking in the Netherlands: An evaluation of changes in travel behavior- further results. *Transportation Research Record 1357,* Washington, DC: TRB, National Research Council.

Hansen, E.R. (1987). Industrial location choice in São Paulo, Brazil: A nested logit model. *Regional Science and Urban Economics,* 17, 89-108.

Hanson, M.E. (1992). Automobile subsidies and land use: Estimates and policy responses. *Journal of the American Planning Association*, 58, 60-71.

Hayashi, Y., Tomohiko, I., & Tomita, Y. (1986). Modelling the long-term effects of transport and land use policies on industrial location behavior. *Regional Science and Urban Economics,* 16, 123-143.

Hensher, D.A. (1994). Stated preference analysis of travel choices: the state of practice. *Transportation,* 21, 107-133.

Hopkins, J.B., O'Donnell, J., & Ritter, G.T. (1994). Telecommuting: How much? How soon?, *Moving Toward Deployment: Proceedings of the IVHS America 1994 Annual Meeting*. IVHS America. (pp. 518-527), Atlanta, Georgia.

Horowitz, J.L. (1986). Modelling choices of residential location and mode of travel to work. In S. Hanson (ed), *The Geography of Urban Transportation* (pp. 207-226). New York: The Guildford Press.

Hunt, J.D., McMillan, D.P., & Abraham, J.E. (1994). Stated preference investigation of influences on attractiveness of residential locations. *Transportation Research Record 1466,* Washington, DC: TRB, National Research Council.

Institute of Transportation Engineers. (1996, No.1). RMOC transportation master plan shapes regional development strategy. *InsITE* (National Capital Section- District 7), p. 5.

Irwin, N. (1994). Telework: A vital link to transportation, energy, and the environment. *Proceedings of Telework '94 Symposium: The evolution of a New Culture* (pp. 182-187), Toronto, Canada.

Joseph, A.E., Smith, B., & McIlravey, G.P. (1989). Consumer preferences for rural residences: A conjoint analysis in Ontario, Canada. *Environment and Planning,* 21A, 47-63.

Kim, S. (1991). Choice of rental housing in Korean market: Alternative approach. *Journal of Urban Planning and*

Development, 117, 41-58.

Kroes, E.P., & Sheldon, R.J. (1988). Stated preference methods: an introduction. *Journal of Transport Economics and Policy,* 12, 11-25.

Lerman, S.R. (1976). Location, housing, auto ownership, and mode to work: A joint choice model. *Transportation Research Record 610,* Washington, DC: TRB, National Research Council.

Louviere, J.J. (1979). Modelling individual residential preferences: A totally disaggregate approach. *Transportation Research A*, 13A, 373-384.

Louviere, J.J., Henley, D.H., Woodworth, G., Meyer, R.J., Levin, I.P., Stoner, J.W., Curry, D., Anderson, D. (1981). Laboratory simulation vs. revealed preference methods for estimating travel demand models. *Transportation Research Record 794,* Washington, DC: TRB, National Research Council.

Lund, J.R., & Mokhtarian, P. (1994). Telecommuting and residential location: Theory and implications for commute travel in the monocentric metropolis. *Transportation Research Record 1463,* Washington, DC: TRB, National Research Council.

Meyer, M., & Miller, E. (1984). *Urban Transportation Planning: A Decision-Oriented Approach*, U.S.A: McGraw-Hill, Inc.

Mokhtarian, P.L. (1992). Telecommuting in the United States: Letting our fingers do the commuting. *TR News no. 158*, pp. 2-7. Washington, DC: TRB, National Research Council.

Mokhtarian, P.L. (1993). The travel and urban form implications of telecommunications technology. Discussion paper for *FHWA/LILP Workshop: Metropolitan America in Transition: Implications for Land Use and Transportation Planning,* Washington, DC.

Morikawa, T. (1989). *Incorporating Stated Preference Data in Travel Demand Analysis.* Unpublished Ph.D. Dissertation, Department of Civil Engineering, MIT, Cambridge, Mass.

Morikawa, T. (1994). Correcting state dependence and serial correlation in the RP/SP combined estimation method.

Transportation, 21, 153-165.

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

Nijkamp, P. & Salomon, I. (1989). Future spatial impacts of telecommunications. *Transportation Planning and Technology,* 13, 275-287.

Nilles, J. (1991). Telecommuting and urban sprawl: mitigator or inciter?. *Transportation*, 18, 411-432.

Ostria, S.J., & Lawrence, M.E. (1994). Potential emission and air quality impacts of Intelligent Vehicle Highway Systems. *Transportation Research Record 1444,* Washington, DC: TRB, National Research Council.

Pearmain, D.J., Swanson, E.P., Kroes, E.P., & Bradley, M.A. (1991). *Stated Preference Techniques: A Guide to Practice,* (2nd Edition). United Kingdom: Steer Davies Gleave, and the Netherlands: Hague Consulting Group.

Pendyala, R.M., Goulias, K.G., & Kitamura, R. (1991). Impact of telecommuting on spatial and temporal patterns of household travel. *Transportation,* 18, 383-409.

Pollakowski, U.O. (1982). *Urban Housing Markets and Residential Location.* Lexington, Mass.: D.C. Heath and Company.

Quigley, J.M. (1976). Housing demand in the short run: an analysis of polytonous choice. *Explorations in Economic Research.* 3, New York: National Bureau of Economic Research.

Quigley, J.M. (1985). Consumer choice of dwelling, neighbourhood, and public services. *Regional Science and Urban Economics*, 15, 41-63.

Regional Municipality of Ottawa-Carleton (1988). *Official plan of the Regional Municipality of Ottawa-Carleton (Volume I: Text).* Ottawa, Ontario: RMOC, Transportation Department.

Richards, M., & Ben-Akiva, M. (1975). *A Disaggregate Travel Demand Models*. Lexington, Mass.: D.C. Heath and Company.

Senna, L.A.D.S. (1994). The influence of travel time variability on the value of time. *Transportation,* 21, 203-228.

Shladover, S.E. (1993). Potential contribution of Intelligent Vehicle Highway Systems (IVHS) to reducing transportation's greenhouse gas production. *Transportation Research A*, 27A, 207-217.

Shukla, V., & Waddell, P. (1991). Firm location and land use in discrete urban space: A study of the spatial structure of Dallas-Fort Worth. *Regional Science and Urban Economics,* 21, 225-253.

Steiner, R.L. (1994). Residential density and travel patterns: Review of the literature. *Transportation Research Record 1466,* Washington, DC: TRB, National Research Council.

Telecommuting Research Institute, Inc. (1991). *Telecommuting Forecasts.* Los Angeles: TRI.

Timmermans, H.J.P. (1984). Decompositional multi-attribute preference models in spatial choice analysis: A review of some recent developments. *Progress in Human Geography,* 8, 189-221.

Transportation Research Board (1993). INFORM: Precursor to Intelligent Vehicle Highway Systems. *TR News no. 165*, pp. 30-31, Washington, DC: TRB, National Research Council.

Weiner, E. (1994). Telework: A vital link to transportation, energy, and the environment. *Proceedings of Telework '94 Symposium: The evolution of a New Culture* (pp. 171-176), Toronto, Canada.

Weisbrod, G.E. (1978). *Determinants of Residential Location Demand: Implications for Transportation Policy.* Unpublished Master's Thesis, Department of Civil Engineering, MIT, Cambridge, Mass.

Weisbrod, G.E., Lerman, S.R., & Ben-Akiva, M. (1980). Tradeoffs in residential location decisions: transportation versus other factors. *Transport Policy and Decision Making*, 1, 13-26.

Young, W. (1990). Land use-transportation interaction: 1969-1989. *Australian Road Research*, 20, 36-47.