Urban Design, Telecommuting and Travel Forecasting Conference
October 27-30,1996
Williamsburg, Virginia

Summary, Recommendations and Compendium of Papers

TMIP

Travel
Model
Improvement
Program

Department of Transportation
Federal Highway Administration
Federal Transit Administration
Office of me Secretary

Environmental Protection Agency

Department of Energy

U.S.Department of Transportation

U.S.Environmental Protection Agency

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Travel Model Improvements Program

The Department of Transportation, in cooperation with the Environmental Protection Agency and the Department of Energy, has embarked on a research program to respond to the requirements of the Clean Air Act Amendments of 1990 and the Intermodal Surface Transportation Efficiency Act of 1991. This program addresses the linkage of transportation to air quality, energy, economic growth, land use and the overall quality of life. The program addresses both analytic tools and the integration of these tools into the planning process to better support decision makers. The program has the following objectives:

1. To increase the ability of existing travel forecasting procedures to respond to emerging issues including; environmental concerns, growth management, and lifestyles along with traditional transportation issues,

2. To redesign the travel forecasting process to reflect changes in behavior, to respond to greater information needs placed on the forecasting process and to take advantage of changes in data collection technology, and

3. To integrate the forecasting techniques into the decision making process providing better understanding of the effects of transportation improvements and allowing decision makers in state governments, local governments, transit operators, metropolitan planning organizations and environmental agencies the capability of making improved transportation decisions.

This program was funded through the Travel Model Improvement Program.

Further information about the Travel Model Improvement Program may be obtained by writing to:

TMIP Information
Metropolitan Planning Branch (HEP-20)
Federal Highway Administration
U.S. Department of Transportation
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Washington, D.C. 20590

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US Department of Transportation
Federal Transit Administration
Federal Highway Administration
Office of the Secretary
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SUMMARY AND RECOMMENDATIONS

GORDON SHUNK

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This conference was sponsored by the Travel Model Improvement Program.[1] There were two principal goals of the conference:

- to improve understanding of the influence on travel behavior of urban development patterns specifically designed to reduce motor vehicle travel and
- to assess the-potential for telecommunications, particularly telecommuting, to reduce motor vehicle travel.

The conference was charged with identifying what is already known and unknown about these effects, what of this knowledge can be applied today for use by Metropolitan Planning Organizations (MPO) and state Department of Transportation (DOT) planners, and what research and development on these subjects is needed to improve today's urban and transportation planning practices. Deliberations at the conference were organized in three subject tracks each of which addressed several specific questions related to its subject.

WORKSHOP 1 -PRINCIPLES OF URBAN DESIGN, CHAIRED BY FRANK SPIELBERG

This workshop enumerated the basic components of urban design and identified which among those components are likely to affect travel behavior. Features that distinguish the "New Urbanism" from conventional development were described. Papers prepared for this session by Edward Beimborn and by Michael Southworth with Eran Ben-Joseph are not included in the compendium of papers from the conference, accompanying this summary.

The workshop then discussed what transportation facilities are appropriate for New Urbanism communities and how those facilities should be designed to serve and blend with these designs. The discussion included consideration of how carefully integrated urban design and transportation facilities affect travel behavior, e.g., destination, mode and route choice.

Finally the workshop enumerated key questions about the design/transportation relationship that need to be answered through further research and development. Principal

[1]The Travel Model Improvement Program is sponsored by the Federal Highway Administration, the Federal Transit Administration, the Office of the Secretary of Transportation and the Environmental Protection Agency.

among these is: What are the mechanisms that cause different urban designs to affect travel in various ways? A major concern is how to increase the consideration of the urban design/transportation concepts and effects in urban and transportation planning in MPOs and state DOTS. Papers by Eran Ben-Joseph, Keith Lawton and Michael Replogle were prepared for presentation in this session; however, only Michael Replogle's paper is included in the accompanying compendium of papers.

Recommendations

There was general agreement that urban design features have important effects on travel behavior and that more research is needed to better understand the mechanisms by which those influences occur. Even if those effects are presently small, the cumulative effects and compounding such effects over time will be important. The workshop discussed several very specific issues related to the influence of site design on vehicle trip generation and parking. These issues will be of considerable interest to traffic engineers, city planners and public works directors.

A basic issue considered by the workshop was how to characterize land use or, stated another way: How do we "measure" urban design?

- What are the important elements of urban design?
- How should these elements be measured or quantified?

One response to those questions is to draw from the architecture and urban design literature and vocabulary (e.g., Madison, Wisconsin, ***"Urban Characters")***. Different elements may be important for different travel decisions; e.g., proximity and diversity of activities for destination choice. Quality of the development on the travel path may influence mode choice.

Research is needed on the factors that influence choice of housing type and location. This is more than simply land use allocation; it goes to the heart of decision considerations and behavior. Techniques that should be considered for such assessments include:

- Stated preference techniques need care to consider problems in representing visual choice.
- Repeated cross-sectional survey studies need careful design (e.g., Seattle housing preference studies).
- Longitudinal panel surveys are another possible technique.

Research is also needed to fully document travel behavior in existing traditional neighborhoods.

Travel behavior and choices are affected by site layout and urban design in both residential and non-residential location. The effects of design of both kinds of areas on travel behavior need to be further studied (e.g., availability of services close to the work place can affect mode-of-travel to work decisions).

There was general agreement that the effects of urban design on all aspects of travel behavior must be studied more thoroughly. This would include more work on the effects of urban design on vehicle ownership. Research is needed on the effects of urban design on destination choice and mode choice, and these choices should be treated as a unit rather than as separate decisions. These analyses will require greater trip type/trip purpose stratification than is typically applied. This examination should be at the household level rather than by traffic zones, especially for walk and bike trips. Many existing pedestrian and bike studies are for college towns. The special conditions affecting such travel should be considered before the transferability of findings from such studies is accepted.

The "substitutability of equivalent goods" effect must be considered in destination choice (i.e., opportunity model vs. gravity model).

Specific Topics for Study

Perception of walking distance (impedance) as related to facade continuity: studies have shown that bleak areas and parking lots interrupt walking patterns.

Parental chauffeuring of children: this should be covered in activity and trip chaining studies.

The issue of personal security as it affects travel choice: personal security in the vehicle, fear of public places, walled and gated communities are emerging concerns.

Reconciliation of Institute of Transportation Engineers (ITE) trip generation rates is needed: these rates are used by many communities to quantify development impacts and by many MPOs for trip generation forecasts. The concern is due to the questionable validity of those rates because of the inconsistency of conditions.

Planning agencies will need to respond to questions about urban design effects, and they need adequate analysis tools and valid data if they are to provide accurate and reasonable answers.

WORKSHOP 2 — EFFECTS OF URBAN DESIGN ON TRAVEL BEHAVIOR, CHAIRED BY BRUCE DOUGLAS

This workshop began with consideration of current policy issues and a review of previous attempts to understand the influence of urban design on travel. The growing awareness of the need to consider and address these effects was indicated. A framework for assessing the current practice in regard to assessing these effects was developed. Jeffrey Zupan provided a presentation on these subjects.

Next the workshop discussed how elements of the travel environment influence travel choices and how urban design features affect the mechanism by which those effects occur. How policy and urban design features enter into that influence was also considered. Explanatory variables that reflect those elements and characteristics were then identified. How those elements and characteristics could be defined and measured and incorporated in travel models were considered. Consideration of the ambiguousness and colinearity in such models was addressed as well. A paper by G. Scott Rutherford, Edward McCormack and Martina Wilkinson presented in this session is in the compendium of papers.

The workshop then turned its consideration to the factors that influence travel. The data needed to support the influential variables were identified along with the potential sources or surrogates for that data. Consideration of how to develop the desired variables from available or potential data was then undertaken. The range of values and travel choice sensitivities for desired variables and how those variables can be forecast was considered. The potential policy implications of using the desired variables were also addressed.

Then the discussions moved to considerations for developing travel models using this new kind of information. The state of the practice for incorporating urban design influences in travel models was reviewed, and several potential model frameworks were discussed. One of these was presented in a paper by Ronald Eash that is included in the accompanying compendium.

Recommendations

One recommendation emerging from this workshop was to develop a synthesis of existing knowledge about the effects of urban design on travel behavior. This is a high priority, immediate need. There should be major efforts to identify and assess existing:

- Urban design/urban form and travel demand forecasting model activities
- Data bases of related urban design and travel
- Current and recent relevant research results
- Research projects pending or underway
- Research proposals that seem to offer merit for increased understanding

This effort will require careful analysis of methods and data quality, not just a summary of results. The assessment should begin with a synthesis of findings from Transit Cooperative Research Program (TCRP) project H-l, which is already 2-3 years old. A network should be established among active and interested researchers and agencies to share and integrate findings.

The FHWA should identify or establish a clearinghouse as a repository for fmdiigs from all related research activity, not just that sponsored by FHWA. This effort has begun with the Travel Model Improvement Program. The clearinghouse should include a web site that would provide periodic status reports and routine updates in old, new or current research activities. The web site should also encourage and facilitate contributions to the clearinghouse from researchers and users or other contributors.

There should also be a newsletter established as a print extension of the clearinghouse for users and other interested persons that do not have access to the web. The newsletter and clearinghouse should provide a summary or digest of information, particularly of new information, added to the clearinghouse. It would also be helpful to provide a less technical reporting process for persons not interested in extensive technical detail.

Research Projects to Enhance Current Practice

Define urban design/urban form:

- Relate urban design/urban form variables to measures of accessibility - spatial, temporal, modal.
- Relate urban design/urban form variables to infrastructure characteristics so transportation agencies, planners and decision-makers can visualize what we are modeling and assess implementation issues.

Identify and rank urban design/urban form variables for origin and destination ends of trips:

- Develop a matrix of impacts and incidence that will facilitate identifying questions to be answered.
- Develop an ordered list of variables to explore: already -considered, under investigation, deferred until later.

Expand research on recent home interview surveys and other travel datasets:

- Include activities that require travel
- Include walk trip data
- Limit additional data collection
- Geocode to census geography

Develop easily derived urban design/urban form variables:

- Reduce need for new data collection
- Include census block density
- Identify street/roadway density, e.g., lane mile ratio

Compare differences in travel behavior with respect to urban design/urban form in different regions:

- Substitution of travel for in-home activities
- Substitution of walk for motorized travel
- Identification of variables with explanatory power

Develop techniques and models to incorporate urban design/urban form variables into current travel forecasting process:

- Reflect modal differences at each step
- Consider and adopt post/pre-processing potential
- Identify methods to forecast change in urban design/urban form variables

Establish a modeling test bed for urban design/urban form research

Consider greater diversity of urban design/urban form, travel choices

Understand linkage between preferences and travel:

Preferences/Needs
|
Activities (long term, weekly, daily)
|
In-home--> Activities <-- Out-of-home
|
Person Trips
|
Walk or Bike vs. vehicle

Data Collection - Needed Research into Demonstrated Behavior

Identify sources for data needed to quantify variables of interest

Existing data files:

- Census data
- GIS layers
- Computations from existing data
- Collected by other agencies (e.g., street geometry)
- What primary collection required?
- Identify primary collection required.

Design data collection programs

Assess data collection costs for variables

Conduct attitudinal and preference research

- Do residents of “urban designed” areas really prefer their environment?
- Is the location selection decision a matter of life-style (long term decision) rather than trip-related (short term importance)?

WORKSHOP 3 — EFFECTS OF TELECOMMUNICATION ON TRAVEL BEHAVIOR, CHAIRED BY PAT MOKHTARIAN

The deliberations of this workshop began with discussion of how and the degree to which telecommunications influence travel behavior. It was concluded that telecommunication would have different kinds, degrees and mechanisms of effects on travel for different purposes, e.g., business versus shopping travel. Other considerations were the effects on mobile workers, e.g., traveling salespersons, the impact of distance learning, delivery of medical services and government services. Papers for this session were prepared by Patricia L. Mokhtarian and John S. Niles.

The workshop then addressed the impacts of telecommunications on homes, neighborhoods and offices. These considerations included how telecommunications affect the location and design of homes and offices and the delivery of community services. The workshop also discussed the effectiveness of community telecommunication centers for reducing travel. Other topics considered in this session included the potential for improved telecommunication from fiber optics, what degree synergistic potential there is between development and telecommunication, and the potential secondary effect on real estate of such synergism. Walter Seimbab prepared a paper for this session.

The final session of this workshop dealt with the effects of telecommunication on urban design and regional form. Of particular concern was the potential for telecommunication to exacerbate suburban sprawl development to the degree that distance and place may no longer impede human interaction. On the positive side it was suggested that telecommunication could be a development tool, facilitating interaction where development is desired, The differences in effects by scale and extent were also considered. Melvin Levin, Roger Stough, Mohammad Tayyaran and A.M. Khan prepared papers for this session.

Recommendations

What do we think we know?

Regarding telecommuting adoption:

- Slower than expected; a significant portion of the workforce either can't, doesn't want to, or doesn't choose to telecommute; and those who do telecommute do so predominantly part-time. Levels of adoption are likely to increase in the future - but perhaps not as rapidly as expected, in part because constraints are often imposed on existing adopters so they quit telecommuting (at least for a while).

Regarding transportation impacts of telecommuting:

- In the short term for telecommuters, there is a clear reduction in trips and peak-period trips (except for center-based telecommuters), Vehicle Mile(s) Traveled (VMT), and emissions.
- However, when the frequency of telecommuting is taken into account, the reduction is a relatively small proportion of telecommuters' total weekday travel. And when the number of current telecommuters is taken into account, the systemwide reduction is a quite small proportion of total household personal vehicle miles traveled (less than 1%). Consequently, energy and emission effects are of similar magnitude.
- Non-work travel does not appear to increase in the short term.
- Current telecommuters (at least those being studied) have longer-than-average commute distances. Assuming commute lengths for future telecommuters are closer to average, the per-occasion travel reductions of telecommuting will diminish, which may adversely affect both non-work trip generation and residential relocation. These counteracting forces are likely to result in future aggregate travel impacts remaining quite flat, even while the number of telecommuters could increase substantially.

Regarding tele-applications other than telecommuting:

- Other trip purposes can be affected by tele-applications in three ways: substitution, generation and modification. The net impacts for any given application may vary, but historically transportation and telecommunications have had a complementary relationship and there is plenty of reason to expect that pattern to continue.

Regarding other forms of remote work:

- The numbers of home-based businesses, part-time and contingent workers are growing rapidly. These categories of workers have very different travel patterns than conventional workers and our current models are not well-equipped to handle those patterns. Similarly, the growth in the numbers of mobile workers (e.g. using cell phone while traveling) may affect travel patterns in the aggregate.

What can be disseminated to MPOs and state DOTs?

- Synthetic model of transportation impacts presented by Mokhtarian offers useful tool for practitioners, both in terms of "typical" numbers until better (or more region-specific) ones become available, and in terms of a structure which combines key relevant factors to estimate telecommuting adoption and transportation impacts.

What do we need to know?

- Great need for accurate data, both cross-sectional and longitudinal, on:
  - the extent of telecommuting
  - the extent to which people are able to and want to telecommute
  - temporal patterns of telecommuting (frequency and duration)
  - magnitude of telecommuting effects (travel modifications, emissions, productivity increases etc.)

- the extent of involuntary telecommuting (hoteling and other non-territorial office arrangements)

- From accurate data we need to further refine models predicting various key factors, including the extent to which people are able to, want to and choose to telecommute, and the frequency and duration of their telecommuting.
- Need to be better able to quantify the trip stimulation effects of telecommuting and telecommunications: increased non-work travel of telecommuters, and the realization of latent and induced demand.
- Better understanding of the impact of telecommuting on residential relocation: aggregate net impact, who is most likely to move and to what type of location (suburb, exurb, leapfrog to next town over, out of the region altogether). Survey movers to understand motivations for relocating, particularly the extent to which the move is influenced by telecommuting and telecommunications.
- Data on home-based businesses and their travel patterns: how many, to what extent are they replacing (rather than supplementing) conventional employment, how do their travel patterns vary from the norm.
- Data on mobile workers and their travel patterns
- Little known on travel impacts of telecommunications for *other* trip purposes: shopping, personal business, work-related, and so on. Substitution, stimulation and modification effects are possible.
- Need better information on the cost-effectiveness of telecommuting relative to other transportation policy measures. Requires an improved ability to predict the demand for telecommuting.
- Need to refine the synthetic model presented by Mokhtarian to make it disaggregate, probabilistic, simulation-based, dynamic.
- Need funding to do research, demonstrations.

Impacts of Telecommunications on Urban Form

What do we think we know?

- Technology is inherently neutral; it can be used to support concentration as well as decentralization. It facilitates location decisions – in either direction – that are motivated or driven by other reasons. At least in the short term, supply does not dictate demand. In the medium term, supply may educate and influence demand.
- Historically, advancements in transportation technology (streetcar, automobile) that increased travel speeds have been followed by increasingly decentralized development. However, these changes have been exacerbated by public policies making fringe locations more attractive.
- Jean Gottman: "It all depends on what people decide to do." Thus, theoretically policy-makers can help shape the impacts of technology rather than passively let them happen, but the "political will" to do so is often absent.
- All else equal, reducing the friction of distance is going to increase the distances people are willing to travel.

- Different types of changes take place at different scales: we see concentration of financial and other specialized activities across different metropolitan areas, together with decentralization within metropolitan areas.
- The announcement of the 'death of distance' has been premature. Distance and location still matter, although telecommunication has somewhat reduced their importance.
- The flexibility offered by telecommunications networks is likely to have a modest effect on urban form as location decisions are dominated by the least flexible networks (e.g., airports) rather than by the most flexible elements.
- Not everyone has equal access to technology. Market forces will at least initially determine who gets what levels of service - e.g. Wall Street will get it first. Need policy intervention to narrow the gap between information haves and have nots.
- Capacity doesn't equal access (you may have the bandwidth or the channel, but not the service). Even among those with access, utilization can vary.
- The accessibility of the technology used in a given context depends on the opportunity cost of the user's time. People with a high opportunity cost (e.g. physicians) will have readily accessible technology; others may have to travel in varying degrees to access technology. For the same person, opportunity costs may vary from one context to the next, resulting in different technology choices.
- We are moving toward an era in which residential location precedes work location choice. This contrasts with historical patterns and is due, in part, to the growth in two-worker households and the low costs of travel. One likely implication is an increase in travel.

What can be disseminated to MPOs and state DOTs?

- Information on what experiments are being tried, what results are being obtained. Even anecdotal information on what works and what doesn't is useful. Need information clearinghouse; make it easy to figure out where to go for information. Need to make relevant information generated by those outside of transportation circles (e.g., state depts. of energy) readily available.
- Telecommuting manuals and other how-to-do-it guidance.

Advice to MPOs and state DOTs:

- Use caution. Planners (and policy makers exposed to popular media expectations) may be jumping to conclusions too fast, buying overoptimistic forecasts of the impacts of technology. This can lead to bad planning decisions.
- Read. Become acquainted with literature *on both sides* of an issue so that you can formulate your own informed judgement about likely impacts, and update that judgement as new information becomes available. Some suggested readings include the Office of Technology Assessment (OTA) report on *Technological Reshaping of Metropolitan America* and the book titled *Telecommunication and the City* by Marvin and Graham. The latter work in particular offers an excellent review of the literature as well as a useful conceptual framework.

- Far from reducing travel, we have seen historically that every transportation and telecommunications improvement has resulted in a net complementary effect on travel (even though substitution also occurs). Hence, MPOs should be worried about how to deal with travel demand that is larger than expected rather than smaller, and spread over a region that continues to decentralize.
- Acquire some telecommunications expertise, to foster creativity in generating and evaluating new ideas.
- Foster the use of technology in public forums (televillage, library) so as to narrow the gap between the haves and have-nots.

What do we need to know?

- General question: How will "changes in the structure of economic activity" (Giuliano) -- such as the rise in small businesses, distributed work teams, flexibility in who-what-when-where-how work gets done-affect land use patterns?
- Specifically, what impacts will strategies such as hoteling and other non-territorial office arrangements have on real estate?
- How effective are telecommuting centers (in terms of institutional viability and travel impacts)? What mixtures of uses make sense under what circumstances?
- How will the increase in the number of self-employed individuals affect residential location decisions?
- We need to think in terms of there being a basket of transportation policies from which we can pick for a region--one size or bundle doesn't fit all. The relative cost-effectiveness of the measures considered must be better understood.
- Need more user-friendly transportation/emissions/land use models for real-time sketch planning, decision support, cost-benefit analysis. Need some prototype simulations to be conducted and made available to planners.
- What are the impacts of telecommuting and telecommunications in rural areas?
- Academics should join forces with practitioners to perform experiments and learn from them. We should also learn from what we do know already.

OPENING REMARKS

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In the field of transportation there is a standard set of planning methods and models that we call the four-step process or the Urban Transportation Planning System (UTPS for short). This set of models and procedures is 'used to forecast travel demand for future transportation systems and it plays a central role in the evaluation of alternative transportation plans and policies, especially capital facilities. These methods are venerable and widely used all over the world. We teach them in universities, use them in consulting firms and metropolitan planning organizations and apply them overseas as well as in the United States. We travel on transportation systems that were planned twenty, thirty and forty years ago using these methods, and the techniques are for the most part, with some variations and improvements, what they were then.

We generally attribute some of these methods to the decades of the fifties and sixties, giving credit, for example, to Alan Voorhees for development of the gravity model in the fifties-the trip distribution'model that is still widely used. There is an article, however, in ***Public Roads*** magazine from the 1920s indicating quite clearly that the gravity model was used in 1927 in the Boston transportation study, and that a succession of procedures that look much like the four-step process was already used in the Cleveland regional highway study in 1928: Our methods thus clearly have roots that are even deeper than is realized by many engaged in the practice of transportation planning.

In the seventies the U.S. Department of Transportation mounted a program of research, development, improvement and dissemination of transportation models and data. It made software available to transportation planning agencies and consulting' firms, ran courses on how to use that software, published manuals and even had a telephone hot line that modelers could call if 'they were having problems with applications. That level of support, the most important of which was the ongoing program of research that supported and advanced the state of the practice over time, went away with the federal budget cuts in the 'early eighties.

Transportation analysis, modeling and forecasting have advanced relatively slowly during the eighties and early nineties; yet there are many new demands being placed on travel demand models, forecasters and policy makers. In addition to the travel demand analysis that has traditionally been done in support of system planning for capital investment, we began to need answers to questions of travel demand management and transportation system management, and the models of the fifties, sixties and seventies' were not ideally suited for those purposes, for example, to determine what would happen if car pooling or HOV lanes were introduced. We grew even more aware of the shortcomings of the techniques in our tool bag when we became increasingly responsible for linking travel demand analysis with air quality analysis, in particular for the development of air quality management plans, implementation plans and conformity analyses required by the Clean Air Act amendments in areas that violate national ambient clean air standards.

Facing new demands and realizing that travel demand analysis was not advancing in accordance with changing needs of transportation policy makers, and realizing that advances in the science of travel analysis were not being reflected in the practice of travel demand modeling, a creative group of transportation officials in the Federal Highway Administration, the Federal Transit Administration, the Office of the Secretary of Transportation and the Environmental Protection Agency got together and decided that it was time for a new initiative to try to update and improve travel demand forecasting. They formed the Travel Model Improvement Program, or TMIP, which has many objectives, all related in one way or another to improving the state of the art and the state of the practice of travel modeling and forecasting. By the state of the art we mean what we are capable of doing - where the "frontier" is in terms of the available models. The state of the practice means what the agencies and consulting firms are actually doing out in the field. Sometimes, of course, there is a gap between those. A large part of the work in the TMIP program is being done under contract because there are few federal officials who are able to devote much of their time and energy to this program.

The TMIP program is divided into four tracks. Track A is devoted to outreach: the dissemination of information, the publication of a newsletter and reports of the research studies that were carried out under all of the tracks, a series of conferences, development of a web site, and preparation of a CD/ROM for the distribution of data sets and forecasting methods. All of these efforts are intended to help modeling and forecasting practitioners sharpen their expertise and promote better practice in the field. Track B is devoted to developing short-term model improvements and changes that can improve the state of the practice currently by adding marginal improvements to existing models and practices. Much of the work in Track B is being done by consulting firms. Information about some of the products of Track B is in documentation available here and in a recent issue of the journal *Transportation* that featured the TMIP program. Track C is aimed at developing a whole new generation of traffic forecasting procedures, and the bulk of funding under Track C is going to Los Alamos National Laboratory where a group of certified mathematical and computer geniuses have been working for several years on development of TRANSIMS, a fundamentally new microsimulation approach that incorporates ideas from activity analysis and insights from research in microsimulation. They are engaging in some demonstrations in large metropolitan areas that include activity analysis, travel forecasting and air quality impact assessment. TRANSIMS is ongoing, and very soon we will be seeing some of its results disseminated to a larger community of interest. Track D involves research and development leading to improvements in data collection and in the databases that transportation planners have available to them to use with their models and forecasting methods.

Among the ongoing changes in transportation planning are two that have brought us to this conference and that must be addressed in all four tracks of the Travel Model Improvement Program. This conference is to consider how travel demand modeling and forecasting can be improved by incorporating some of the changes that are occurring in approaches to urban design, and in the simultaneous substitution and complementarity occurring between telecommunications and travel. These two areas are related to one another but each is important in its own right.

Many of you are interested in how the physical characteristics of residential neighborhoods, commercial centers and downtown areas can be changed to bring about more desirable and more efficient travel patterns. We are increasingly calling for more attention to land use mixes; street patterns that encourage walking, cycling and transit use; the concentration of higher densities of activities in corridors that are well served by public transit; the creation of pedestrian or transit oriented districts, and to traffic calming. We do not know exactly which of these strategies will have deep, lasting and significant effects on travel patterns, in part because we do not have evaluative tools with which to estimate their long-term effects. If you are interested in promoting these approaches to planning it is really important that they be institutionalized and the way they become institutionalized is through devices like travel demand forecasting techniques and data collection techniques that are standardized. If you are interested primarily in tools and techniques as an analyst, forecaster or consultant, it is important that you begin to be seriously concerned about these newer approaches to travel demand management being promoted by so many communities of interest. We are not here to advocate particular changes or to rate some land use approaches as better than others. Rather, we have come here to ask what changes need to be made to our methods of analysis to enable us to ask whether some approaches to urban design in particular contexts might be better than others with respect to efficient patterns of movement in cities and suburbs.

Right alongside the movement to change travel by changing the design of urban places is the realization that telecommunications technologies are interacting with transportation systems and with human activity patterns in new ways. We are connected with one another by telephones, fax machines and the worldwide web, and it is important that we are cognizant of the ways in which those circumstances are changing the ways we work, changing where we live, changing the frequencies and the times at which we travel and changing the spatial patterns of activities as well. Very important is the question of how we can capture these emerging changes in our travel demand modeling tools and techniques. We are asking you all as experts and thoughtful observers to help us come up with concise and useful statements of what we know in answer to these questions about how these things are changing, how that change affects travel patterns, particularly the distribution of travel in time and space. We are asking you to ponder what we already know about the effects of telecommunications and the effects of alternative urban forms and urban designs on travel and what can be disseminated in the near future to metropolitan areas, state departments of transportation and consulting firms in order to improve the quality of their transportation forecasting and policy making. We are also asking for help in identifying ideas for research, development and demonstration that are needed to improve the state of the practice as well as the state of the art with respect to the topics of this conference.

KEYNOTE ADDRESS

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When I was asked to come here to give this keynote speech, I asked: Why are we having a conference on urban design and telecommunication ? The first question to answer is why urban design and telecommunication are in the same conference, so I will address that first. I will then ask what do we know, and the what do we know questions will be in very general terms, because later you are going to hear from the real experts, the people who have done most of the research. I will ask: What do we know about urban design, what do we know about telecommunication? Then I am going on to ask the question about large-scale implementation, because if anything is going to happen, things have to be implemented on a wider scale than we are seeing today. Finally I will talk about the larger context of economic and social issues.

Why urban design and telecommuting ? If we really feel that we have to impose some controls on the use of automobiles, the way to do that is pricing. We would also say that pricing is really difficult. There are many difficulties involved in changing the price of automobile travel. At the same time, we have to respond to air quality and other environmental concerns. We have concerns about fragile habitats, about preserving open space, noise, about toxics, and all sorts of other things. This long list of issues is related in some way to transportation planning and particularly use of the automobile. So what do these two strategies have in common from a public policy standpoint? They have in common the fact that they are win-win. They give people more choices, and they make people better off. Unlike pricing policies, there is really no pain involved from' an individual standpoint. These are both strategies that provide more choices for housing and work location, and at the same time reduce automobile use and achieve environmental goals.

The key question to answer is: Do either of these policies significantly affect travel demand? Are the anticipated reductions in automobile trips and VMT (vehicle miles of travel) documented in a rigorous manner? Are these changes significant enough to merit consideration in a new generation of planning models? Since a good part of the TMIP program is about making better planning models; this is a key consideration.

Now about urban design, generally called in planning circles the new urbanism. It is a combination of concepts, referred to as TND (traditional-neighborhood development), or NTND (neotraditional neighborhood development), or TOD (transit oriented development).

This concept is a reaction to the standard planned community developments seen in the suburbs today. The basic idea of new urbanism is to provide people with a more friendly neighborhood. Its characteristics are:

1) to mix different kinds of land uses together, that is, residential and non-residential;
2) to vary densities of housing to accommodate varying income groups;
3) to achieve higher development densities compared to what is standard in suburban areas today, and
4) to use gridlike street patterns to make nonmotorized, that is, bicycle and pedestrian, movement more direct and efficient.

There is also an emphasis on neighborhood services (community services, neighborhood retail concepts) to give people the opportunity to engage in everyday nonwork activities close to home with the idea that some would walk or take transit or not drive alone to those activities. The goals are to encourage less private vehicle travel through promotion and provision of high quality transit service as well as bike and pedestrian movement and circulation. Another goal is to balance jobs and housing, giving people the opportunity to work close to home. There is also another level of goals less relevant from a transportation perspective: a focus on local community and social cohesion, and an effort to develop through a new design paradigm more socially diverse communities.

There has been tremendous interest in what happens in these "new urbanism" communities, but they are not around yet. There are six or eight actual large developments based on these concepts. The first, Seaside in Florida, is a unique situation and therefore is not a good basis of comparison. The others are in varying stages of development. Consequently, many researchers are trying to research something that is nonexistent. One choice is to look at comparable situations, so we look for existing neighborhoods that have similar attributes to the TND concept; then we look at people's travel behavior and compare travel patterns in TND- like neighborhoods with those in traditional or conventional lower density suburban neighborhoods. A second possibility is to simulate that kind of community and population and see what happens. If you think about the principles on which these communities are based, there are conflicting incentives with respect to travel demand. A grid system does not give more accessibility to pedestrians and bicycles; it gives more accessibility to motor vehicles. So all else being equal, we might consider that there may be more motor vehicle travel as a result of the grid street system. On the other hand, if the accessibility is more concentrated, we should expect to see more nonmotorized travel. If we also accompany these developments with high quality transit, better transit should promote more transit use. Whether transit and pedestrian use are encouraged, and whether there is more travel by those modes does not necessarily translate into less motor vehicle travel, since more accessible neighborhoods may stimulate more total travel. Results are still somewhat mixed. In terms of comparative studies, we find generally that there are in fact fewer motor vehicle trips in TND-like neighborhoods when we make these comparisons. There are generally more transit trips if the comparisons are in neighborhoods with high quality transit, and there are also more pedestrian trips. Findings are not consistent, however, across all studies. Another problem associated with this research is that in many cases other factors are not held constant. Raw comparisons of density and trip generation are often made without sufficient attention paid to all of the different characteristics of the population and the micro geography of places that are also part of this equation. There is also the problem of relative location; no matter how hard we try, the fact remains that most TND type neighborhoods are located closer to the central core of metropolitan areas than suburban low density conventional developments. There is a spatial relationship here that is related to the total accessibility of the metropolitan region and to people's overall preferences of central or close to central location versus suburban or even exurban location that is very hard to control for in this type of research.

In reviewing this research, I find the reduction of automobile trips associated with TND-type neighborhoods to be most uncertain. Any travel savings that might accrue are highly localized for short neighborhood trips. If we are looking for ways to alleviate congestion, these are the kinds of trips that are made in uncongested areas anyway. These short trips really have no impact on the 'regional system. The question is: Do these have any indirect effect that might be positive from an air quality or other environmental standpoint?

What about broader implementation.? If we are to develop models incorporating these kinds of characteristics, we must make a case for what we would see if we were to take this TND concept and implement it on a much broader scale. The first issue that comes to mind-is what I call the self-selection problem, or what econometricians call endogeneity, the question of how we choose our neighborhoods and where we live. I know that most people who prefer to use transit and are, to some extent, transit dependent are going to try as much as possible to choose locations that are transit accessible both to live and to work. The question is: If we provide this new urban form on a large scale, are we going to get the same returns from it that we might have seen in these earlier studies? This is a big question that remains to be answered.

Another big question is: What is the market? I teach in a school of urban planning and development. We have a planning degree and a real estate degree, so we talk often with developers; We learn a-lot about the development process, so I always have to ask: Is there a market; could we do this in the marketplace.? The record does not look too promising at this time. First of all, most of the developers of these major new urbanism projects have had tremendous financial problems; they have had to restructure loans, they have almost gone bankrupt, or have gone bankrupt. Proponents say that this was all the recession, that they all started at the wrong time. As you know, we had a terrible recession in the housing market, and proponents claim that once the housing market turns around everything will be fine. Critics say that the infrastructure cost of these developments is very, very high, and as a result, there has to be a premium on the homes sold. From a profit standpoint that puts you into the middle upper class or move-up market. There is a real question about how we can we develop truly mixed neighborhoods, given the economics involved in these developments.

Existing efforts to build these projects have been located in suburban areas, not urban areas, often in fairly remote locations far from job centers and far from transit. In such locations, it is hard to. imagine that travel patterns would be any different. I asked one of the developers who was a marketing person for these kinds of TND type developments, "What is your rule of thumb, how do you decide where to build a project like this?" His remark was, "As long as it is within 30 miles of a job-center, we can do it." That is not exactly the architectural dream that was developed around new urbanism. The other consistent problem is the neighborhood retail element. We live in a world where people shop once a week, and where people are more than happy to jump into their minivans and go to Home Depot or Wal-mart to save a few dollars, so there is a real question about the financial viability of neighborhood retail. Developers argue that they have to subsidize the local retail or it does not exist. If developers are subsidizing the retail, the purchaser is paying a higher price for the house and is just paying for that service in another way.

The other issue that always comes up is the new urbanism concept versus lifestyle preferences. We have not seen a lot of overt activity that tells us that people prefer to live in higher densities in order to be close to jobs. In fact what we see is the reverse; we see that people are quite willing to drive long distances in order to live in lower density circumstances. One of Bob Cervero's students gave a paper at another conference recently, and his analysis showed that if we were to pursue higher density developments (mixed use developments near job centers) one of the outcomes might be even longer commutes as people who preferred lower densities were forced even further away from job centers. Although some people would live closer, some would live even further away, and the net effect on commuting would then be unknown.

Another lifestyle question is the issue of neighborhood shopping versus "big-bucks" retailing. The neighborhood idea of people running down to pick up a few things at the store, which -is all you do if you are on your bike or walking, does not really complement current lifestyles. People are under tremendous time pressures, and we see great efforts to economize and save one's time. It seems difficult to believe that there would be much business at the neighborhood level. What we see instead are these incredible economies of retailing in the form of "big-bucks" retailing, and people seem to be quite happy to drive 10 to 15 miles to go to these places. That is what we are seeing now in the real world.

Another point that I think a lot of people lose in the discussion is the "opportunity cost" of neighborhood activities. The only places where we see thriving small-scale neighborhood activities are either in rather high-end neighborhoods, where there are gourmet/boutique types of goods being sold at a premium price, or in the ghettos of the inner city where people lack accessibility and are forced to shop close to home at "mom-and-pop" stores. There is much evidence that indicates that prices are higher there as a result. There is a substantial downside at least in the real world of today's existing neighborhood retailing.

Let us go on to telecommuting. For telecommuting I chose to use a narrow definition of those who have a regular workplace provided by the employer but who work at home or somewhere else part of the time. We have two categories of telecommuters: one is home-based and works at home one or two days a week; the other is center based and works at some remote facility closer to home than the conventional workplace. It is important to note that home-based workers are not necessarily telecommuters. There are all sorts of home-based workers, some self-employed and some doing other things.

Is this a complement or a substitute? In other words, will telecommuting and the use of telecommunications technology in the long run reduce the demand for travel because it is a substitute for travel, or will it in fact act as a complement to travel, meaning that the total amount of interaction will increase as a result of this new form of accessibility? The analogy is e-mail: although your phone may not ring nearly as much, you can be answering e-mail for hours, and your total amount of interaction has definitely increased.

The question, in terms of the strict definition of telecommuting, is that if people do not have to travel to the office quite so frequently, what happens? Clearly there is an incentive from a theoretical standpoint to take some of these savings and move even further away from work.

Secondly, it is possible that commuting savings may generate more nonwork travel of one form or another. It. is also possible that telecommunting will generate more motor. vehicle commuting, when commute costs go down, we are more likely to prefer the highest quality mode -driving alone. Those are all possibilities.

According to Professors Mokhtarian and Salomon, research on home-based telecommuting that is both longitudinal and cross-sectional suggests, at least today, that the savings from reduced commuting are not entirely offset by other types of travel. There is a net reduction in travel at least as far as we know, at this point. In the case of center based telecommuting, we have a, different story, because people still have to go to the center. That means they are taking a trip, so perhaps we have. some, VMT savings, From, an air quality standpoint, center-based telecommuting is at least questionable. At this point we do not have any, evidence that telecommuting promotes more dispersion, or longer distance commuting, but we do know that people with the longest commutes are most inclined to telecommute. Moreover, if telecommuting is more broadly implemented, average trip distance for telecommuters will decline, and we will see a reduction in any type of travel savings.

What about broader implementation of telecommuting? One of the things we are finding out is that the telecommuting rate remains surprisingly low, considering, its attractiveness., We also have very few examples of profitable telecommuting centers. We have numerous subsidized centers, but we do not have many that are making a profit. According to. the statistics I have, it is still true that fewer people telecommute than walk to work, and fewer people telecommute than take transit. We are talking about a very small share of commuters. ,The obvious question is why is this happening, and it looks as if barriers to more widespread telecommuting are institutional, social, and organizational, not technological. There are issues of supervision and productivity-the boss does not want the worker where he cannot see him, There are questions about attachment to the employer: if you are spatially separated from the-organization,. do you then lose your affiliation and loyalty to that organization and become a less motivated employee? From the employee's perspective there are the issues of access to internal information. If you are not seen at the'workplace, are you going to get the promotion? At home, there are numerous issues related to the conflict between household and work activities under the same roof.

Now let me talk about the larger context. We are only beginning to see the impacts of technology on society. That is just a small, partial list of some of the things that are going on. First, the growth of home-based shopping, home-based entertainment, home-based education and training and, home-based employment.. Second, in. terms of service provision,-we have financial, medical and legal services being offered remotely. On rather frightening example. is a type of surgery that can .now be done remotely; the doctor is at his computer; the patient .is thousands of miles away, in a hospital, and robotics is used to conduct the operation

We. are. only beginning to see what. the future holds for all of us. The changes are structural and fundamental. It is not just a question of using technology and adapting it to current modes of working; things are changing much more than that. Information technology is related to what a lot of regional scientists call economic restructuring-fundamental changes in the way economic activity is organized. Those changes mean a tremendous rise in small-businesses, which we are observing, a shift to networked production methods, globalization, and flexibility; flexibility in production, and flexibility in the use of the labor force. Work is changing. Today's young people will have a very different experience in terms of their working careers. Whom will you work for? You are going to work for many people. The career job of 25-30 years is coming to an end. You will work for many people over a period of time. You may also be working for yourself as a self-employed individual; you may be working on a short-term contract, you will work in all sorts of different ways. What are you going to do? You are going to do different things. The world is changing so quickly that you are going to have to be retraining rather consistently and constantly. When are you going to work? You are going to work at almost any time. We already have stockbrokers on the west coast whose day starts at 2:00 A.M. There are others who stay up all night because they are plugged into the global market in Japan or elsewhere. We know that people's hours are becoming more flexible, so we know that they are not working 'the conventional 9-5 in the numbers that they once were. Where will you be working? You may work at home, or from a mobile or temporary office, or for an employer downtown, or in the suburbs.

These are the only facts I am going to give you to demonstrate how things are changing. This is U.S. Census data, showing the percent change between 1980 and 1990 for the United States as a whole. Over that period we had an 18.5 percent increase in total employment in the United States. Self-employed persons increased by 20.8 percent. The number of people working at home increased by 56.2 percent; the number of people working part-time increased by 23.1 percent. Perhaps more surprising is that the number of people working more than 40 hours a week increased 40.7 percent, and the temporary workforce (from another data source) between '1980 and 1988 increased 175 percent. Kelly Services, for example, is one of the largest and fastest growing employers in the U.S. Since 1990 was a boom year, we could attribute at least some of that increase in working more than 40 hours per week to the booming economy. My suspicion is that it is more of a long-term trend. Corporate downsizing and streamlining results in a reduction in the size of the core labor force and more intensive utilization of the this labor force. There is also some indication that the number of people with more than one job is increasing.

From a travel standpoint, what does all this mean? The first thing it means, and these are all things that are highly relevant to planning and modeling, is that the work trip is no longer regular or predictable.' It is no wonder that we see the work trips spread all over the day, given what is happening in the economy. What we would expect to see, although there is no evidence at this point, is more work related and personal business travel. As the share of work trips goes down, we should be seeing work related and personal business travel going up. We should see less peaking of demand, because work is more flexible and will become even more so. Flexibility on the production side leads to more freight traffic demand, probably in smaller lots, as just-in-time inventory and other such practices should be generating more freight traffic. We should also see greater separation of home and work. If I do not know where I am going to be working next year or five years from now, it will be most difficult (or impossible) for me to be located close to that job. Therefore my expectation is that we will see people living further from their work rather than closer. The weakening of the linkage between home and work leads me to believe that amenities are going to play a much greater role in location choices. If we cannot live close to our jobs, we can live close to trees, if that is what we prefer, or we can live in the central city if that is what we prefer. In other words, both households and employers are becoming more footloose. All of that translates into what is an utter nightmare for modeling: more uncertainty. Although travel patterns are difficult to predict now, as this flexibility works its way through the economy, prediction is going to be even more difficult in the future.

Conclusion

We need to consider urban design and telecommuting in this larger context. The implementation of new urban design concepts really requires success in the marketplace; the ideas that are going to be successful are those that are adaptable in the marketplace.

I live in a high growth area, and one of the things I am fascinated by is the adoption of TND attributes or concepts by mainline developers in mainline. suburban development. We now see houses with porches, but they still have three-car garages. We now see these houses fronted to the street, and they look very nice, but they are still on cul-de-sacs, and if they are not on cul-de-sacs, they are still isolated from a functional standpoint. We are starting to see these adaptations, but it may not be the picture that planners and architects have in mind. Despite the huge number of papers and articles produced on this subject, we still need more research to understand travel impacts. Much of the existing literature has been produced by advocates, and many studies lack appropriate methodology and data. In addition, as I noted earlier, some aspects of new urbanism certainly conflict current and likely future lifestyles.

With regard to telecommuting, implementation has been limited by social and organizational constraints, not by technology. Our ideas of telecommuting are based on an old conceptual model, it is using technology in the traditional workplace. Since we may have fewer traditional workplaces, that is not where the “action” is, and I think you are going to hear that many people are thinking in this direction. These more fundamental changes will have greater effect, and they are happening under the control of no one in particular. We certainly do need to consider these broader effects of information technology on all aspects of travel.

URBAN DESIGN ISSUES RELATED TO TRANSPORTATION MODES, DESIGNS AND SERVICES FOR NEO-TRADITIONAL DEVELOPMENTS

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What I thought I could best do in my allotted time here is to talk briefly about how urban design, what I prefer to call the built environment, affects travel. First, I will review principles of how one creates built environments that meaningfully affect travel, and then look at some ecological dilemmas in measuring these impacts. Then I will turn to several studies my students and I have been involved with during the last several years addressing this question, quite admittedly only coming up with partial insights into these questions. I will try to show how we have tried to add some degree of sophistication and new methodological approaches to hopefully better illuminate our understanding of the subjects. Indeed, much of that work has involved triangulating research designs. We have tried to look at these relationships using different data sets and different methodological approaches and, hopefully, collectively we begin to get insights and patterns. Let me begin with this simple view graph which shows on the top Kensington, Maryland, in 1890 and on the bottom Seaside, Florida, in 1990 a century later. I think it pictorially shows what many traditional town planning principles are about. They borrow design themes and elements from turn-of-the-century American communities, often New England towns and Southern towns like Williamsburg, and try to graph them on a contemporary urban fabric. A dominant feature of the traditional town is a walkable scale wherein many activities are within a quarter to half mile of residents. You see in both designs-Kensington and Seaside-a modified or broken grid patterns of streets. The idea is to open up as many more connections and destinations as possible through a finer grain grid. Traditional towns also feature prominent civic spaces in the core such as a school or a civic center. Central squares serve as a gathering place for the community, where people congregate for parades, demonstrations, celebrations, and everyday events. Mixes of land uses, housing types, and densities are also prevalent, as are rear lots and back alleys.

It is very important to recognize at the outset that transportation and mobility are not the key objectives of these traditional neighborhood designs. First and foremost urban designers are trying to instill a sense of community, an attachment to place. To some degree, there is an undercurrent of social reform behind these designs. Advocates are trying to create environments where suburbanites are less confined to their cars; instead, the hope is to have people from all walks of life interacting, face-to-face, on a regular basis, thus creating a more-socially and culturally diverse urban environment. Studies might show traditional neighborhood designs have very marginal impacts on travel, however, this does not mean we should not create such places. They may be worthwhile doing for other reasons. If nothing else, they are widening our choices in living, working and traveling environments. Anything which expands choices in this postwar era of stereotypical; cookie-cutter suburbandevelopment is a very positive thing.

When thinking about the delicate relationship between travel behavior and urban design it is instructive to think about the three D's, or dimensions, of the built environment. These three dimensions-density, diversity, and design-characterize the prominent features of neo-traditional communities, new urbanism, transit oriented development, or any other urban design scheme. First, let's take density. Most people respond very viscerally to the notion of density, though quite simply we are talking about settings where places are closer to each other. There have been many studies on the effects of density on travel. Here we see a graph where fuel consumption rates per capita decline as a function of residential density, and here we see transit modal splits go up as a function of residential density. The problem is these studies use a simple two-dimensional plane to relate to travel behavior. Many share a strong elastic relationship, however, when you properly control for other factors like the tendency for higher density areas to be home to lower-income households. You find that the contribution of density itself becomes fairly marginal. Most studies show that the big mobility payoff comes from going from low to moderate densities. Plotting trip rates on the vertical axis and density on the horizontal axis shows you get the biggest drop going from extremely low densities to moderate densities. Thus, we are not talking about Hong Kong style densities or even three-story garden apartments everywhere to achieve significant benefits. Often it is when going from about 4 to 5 dwellings per gross acre developments to 12 to 15 that you find the most significant gains in terms of reducing travel consumption. Accessibility is another index of densities or relative proximity. In certain ways, it is an index of how unspread-out development is. To the degree that destinations are relatively close, accessibility is high. People like Reid Ewing have shown that accessibility is the more dominant explainer of people's travel behavior within the communities than is density in and of itself. Of course, density is really a proxy for other things. Dense places tend to have better quality transit services, lower parking provisions, and lower average household incomes. It is all these other things that accompany densities that are really shaping travel choices.

"Diversity," or mixed land uses, is another defining feature of design initiatives in vogue like new urbanism. We are talking about mixed use. A suburban retail strip has mixed uses, but is hardly an urban design paragon. The notion of diversity is land uses that are compatible and that benefit from being close to each other. For residential neighborhoods, the aim is to provide shops within the community. One that convenience trips-trips that people might otherwise be compelled to use their cars and drive out of the neighborhood-are instead made by foot, bicycle, or alternative modes if shops exist within a neighborhood. Retail within neighborhoods might also have some effect on inducing people to use transit to commute to work. Transit commuters can conveniently stop off at the cleaners or the grocery store when retail areas are sited near transit. For offices and other nonresidential land uses, probably what is less understood about mixed land uses is that they can be important inducements toward car pooling or public transit commuting. Those working in a suburban office park with on-site restaurants, retail shops, and ATMs, are going to feel less stranded if they ride share or take transit. Workers retain some midday mobility by virtue of having those activities on site. For the secondary trips, like heading to lunch while at work, mixed uses can induce walking and cycling. Of course, mixed land uses have far more important implications beyond just travel behavior. They allow for more efficient use of land, like shared parking. Office parking can be used evenings and weekends by, say theatergoers if an entertainment complex lies near an office center. Diversity also relates to housing mixes and modal alternatives. In the suburbs we have experimented some thirty years with fixed-route, fixed-schedule bus service, and still transit carries a small fraction of trips in most areas. Why. not open the marketplace to jitneys and commercial vans which can provide superior door-to-door services.? By diversity, then, we mean more modal options and live/work options. Diversity cuts across a very wide array of contexts.

The third D in the three dimensions of the built environment is "design". This is perhaps where the neo-traditionalists feel they have the best chance of changing the suburban landscape, by creating grid street patterns, planting street tress, resiting parking,' and ensuring high-quality pedestrian provisions. I was scolded a few years ago 'when 1 used the word "pedestrian amenities" during a talk. The word "amenity" suggests that we are giving some kind of freebie or frills to pedestrians. Of course, what designers really have in mind is leveling the playing field. The aim is to give the same basic provisions to alternative means of conveyance, like walking and cycling. So it really is a question of basic provisions. Site designs, like providing rear alleys, situating parking to the rear, and all the things that neo-traditionists and new urbanists tout as important-and likely have greater social value than transportation benefits. These are things that can begin to bring people together, promoting social interaction and comradery. Transportation is clearly secondary.

The debate over preferred street patterns in suburbia has heated up.recently. Randy Crane and a few others have published papers recently contending that the potential benefits of grid street patterns are highly dubious. On the one hand, gridded streets can encourage walking, however, on the other hand, they also increase accessibility for motorists. Their ultimate impact likely depends.on the grains of streets and block patterns. Grids laid out in superblocks will probably induce automobile trips. However, a very fine grain grid-what neo-traditionalists call for-with intersections 400 or 500 feet instead of every 1,500 to 2,000 feet, will likely deter motoring. Where cars must stop repeatedly, as with four-way stops, and where preferences are given to pedestrians and cyclists, one is less inclined to drive a car. Thus, I would argue, it is not so much the configurations of streets as it is the grain of designs that are likely to bear on travel behavior. When researching this topic, one has to dig deeper to get a sense of the grain and the details of designs characteristics before one can even begin to understand the effects of new urbanist designs on travel behavior.

Researchers face a number of dilemmas when trying to discover how built environments affect travel demands. To study the influences of mixed land uses and pedestrian-friendly designs on travel, the biggest impacts are likely to be on nonwork trips, and shop trips specifically. Most regional travel surveys, however, rarely have more than two to four household trip records for any one census tract neighborhood. With so few cases it is very hard to associate the designdetails of neighborhoods with travel demand. The reality is that regional travel surveys are designed to guide investments in large scale regional transportation improvements, not for neighborhood scale planning. In the transportation field. we have been blessed with rich data. Since the collapse of HUD's 701 funding for comprehensive planning, we do not have particularly good region wide *database on land uses, and virtually nothing on urban design features. To complete data on urban design, one is left with doing primary data collection and maybe drawing information from often incompatible secondary sources. At the neighborhood tract level, quality and compatibility of urban design and land use information lag seriously behind that of travel data. Statistically, obviously co-linearity problems abound. While I have suggested that built environments sort themselves rather neatly along three dimensions, the reality is that most dense places also tend to be diverse and pedestrian friendly. They also generally enjoy better transit services and parking is more limited. It thus becomes difficult to attribute higher rates of transit riding to density, per se, when these other factors co-exist. Maybe it is counterproductive to attempt to statistically isolate the influences of any one element. What is really important is the synergy and the interaction among factors.

Another dilemma facing researchers is the richness of data. Where we do have land use data and urban design information is often recorded on a simple nominal scale-often binary where either the condition exists or not. For example, a measure of pedestrian provisions is as simple as whether a sidewalk exists or not. Such "dummy variables" are frequently used as crude indications of urban design features. The dilemma is that control variables that go into these analyses, like the price of travel or household income, are much richer, measured on a metric scale. Thus, the predictive odds are often stacked against land use design variables, because of how we measure them and because of the absence of enough rich variation.

Another dilemma of researchersis confounding influences. A lot of developments came on-line in the late '80s and early '90s when real estate markets began to soften and go flat. Projects like the Kentlands in Maryland, a Georgetown look-alike in the suburbs, went belly up and the banks had to assume ownership. What probably had a bigger effect on reduced congestion levels in the early '90s than new urbanist designs was higher unemployment, meaning fewer people were making work trips. Another confounding factor is that many progressively designed places, like developments, invariably introduce TDM programs as well. With cash-out parking, free transit passes, guaranteed rides home, and so on, it is hard to separate out the influences of these policy initiatives from the influences of urban design.

What I want to do with my remaining time is to review several studies that have sought to address and overcome these dilemmas. One approach to deal with measurement and control problems is to take matched pairs-that is, match up neighborhoods which in many characteristics are similar except for their design features. Ideal matches would have comparable incomes and vehicle ownership rates, and comparable levels of transit services, and lie fairly close to each other, but would greatly vary in terms of their design characteristics. When one cannot empirically measure a phenomenon, another approach is simulations. To date, most simulations of urban designs have concentrated almost exclusively on the effects of grid-iron streets and networks. For the most part, these simulations have pretty much assumed the densities and the other design of comparison neighborhoods to be comparable. While this allows researchers to estimate the likely effects of gridded street networks on travel demand, it misses the fact that design treatments need to be bundled together to really begin to exert meaningful influences. Of course, prices probably have the strongest bearing on travel choices. Unless the right prices are set, we are really always scratching at the margin in terms of altering travel behavior through land use initiatives and urban design. Free parking will greatly over shadow any possible influences that urban designs might have on travel choices.

Another approach to understanding the link between travel and design is international comparisons. I certainly have sought to gain insights by looking at experiences abroad, but invariably one must contend with the criticisms of cultural and historical differences in places like Europe and the U.S.

Lastly, the most popular and potentially powerful tools for drawing statistical inferences are predictive models like regressionand logit analyses. For the sake of keeping this simple, I will just move on and talk about the application of these techniques in a few minutes.

One study that attempted to cope with many of the methodological dilemmas just outlined is Michael McNally's recent work in Orange County, California. Using 1991 SCAG data and cluster analysis, McNally classified census tracts in Orange County as either:

1) a traditional neighborhoods;
2) Planned Urban Developments (PUD) (e.g., contemporary tract suburban designs); or
3) A hybrid of the two.

McNally used network densities and measures of accessibility as the chief clustering variables. His study showed that indeed traditional neighborhoods averaged significantly lower vehicle trip rates (2.95 trips per household per day versus 4 trips). It is important to note that such studies only consider vehicle trips since regional travel surveys do not usually count pedestrians movements. Thus, there is a built-in bias right at the outset against even recognizing and thus potentially planning for nonmotorized travel. A shortcoming of this study, however, is that Orange County is hardly a place of great land-use diversity. It is probably as uniform of a suburban landscape as can be found in America. I assume that the lower trip rates are partly due to the fact that those who live in older parts of Orange County, like Santa Ana, that feature grid-iron streets and higher densities are disproportionately recent immigrants from lower income households. Thus, are the lower trip rates due to traditional designs, lower income, or both? Such studies cannot really answer this.

Let me briefly review a few other studies that I have been involved within the last three or four years that have sought to cope with methodological dilemmas. One study focused mainly on the question of mixed land uses and their effects on commuting using a database that contains numerous control variables, the American Housing Survey (AHS). The American Housing Survey provides a wealth of data on neighborhoods and travel for about 80K. households across some 44 metropolitan statistical areas. Data are compiled by housing unit, not household. There is information on whether a retail, grocery, or drugstore lies within 300 feet of a surveyed residence. We created a simple dummy variable to signify whether housing units have commercial/retail activities close by and as far as a mile away. The AHS also has an ordinal measure of housing densities as well as a wealth of control variables, like household incomes, vehicle availability, and transit service adequacy. Using regression and logit models, we found the presence of neighborhood shops had the biggest effect on promoting walking and bicycle commute trips. A weakness of the AHS database, however, is that travel information is available only for work trips, for a home-to-work commute distance of one mile, a 20 percentage point differential in the probability of commuting by foot or bicycle, depending on whether someone lives in a mid-rise/high-rise mixed use setting versus a low-density single-use setting, controlling for vehicle ownership levels and other potential explanatory factors. Thus, a single-use, mid-high rise built environment was found to produce very comparable. walk commute modal splits as a low-density, mixed use one. That is, mixed land use added as much as increasing densities from low to mid-rises in encouraging non-motorized travel for commutes up to one mile in length.

Another study I recently led that tried to deal with control problems involved matching pairs of communities in the San Francisco Bay area. Because we relied on the census transportation planning packages we were forced to limit our analysis to commute trips. What we were able to do was find suitable comparison neighborhoods: one set of neighborhoods that was developed prior to World War II, at one time had a key system street car services, and higher densities yet comparable transit service levels as comparison neighborhoods. In matching neighborhoods, often lost because a more transit-oriented places tend to be rewarded with more transit services, becomes nearly impossible to remove this influence). We did not find tremendous differences in commute trip rates or modal splits among matched pairs of neighborhoods. For the seven matched pairs, there were hardly any differences in the percent of work trip made by mass transit, no more than two to three percentage point variations. Clearly other factors, like the relative price of auto travel and levels of regional accessibility, influence transit modal splits more than neighborhood designs. We also found about a 4 to 12 percentage point differential in walking modal splits between traditional neighborhoods and auto-oriented ones, controlling for income levels and other possible explainers.

In a follow-up study we focused on travel differences between two Bay Area neighborhoods that were comparable in all respects other than urban design. We actually sent out about 6,000 travel surveys to residences of two communities in the San Francisco Bay Area, Rockridge and Lafayette, both east of Oakland. The two neighborhoods are on the same Bay Area Rapid Transit District (BART) line, are served by the same freeway, and are about five miles from each other. They also have very comparable median household income levels. Besides having decidedly different built environments, the only other notable difference between the two neighborhoods is that Rockridge has a high share of students, but we netted this out of our analysis. Rockridge is a traditional neighborhood in many respects. Its main street, College Avenue, features a street wall of commercial-retail uses. Residences on cross-streets to College Avenue consist largely of California bungalows with rear in-law units. Rockridge has moderate residential densities. Lafayette is Rockridge's polar opposite. Near its BART Station one finds a completely different environment consisting of spread-out strip development surrounded largely by parking lots. We found about a 10 to 20 percent higher share of nonwork trips by non-auto modes among residents of Rockridge. Probably most importantly, we found a much higher share, 18 to 20 percent age points, of walk access trips to BART, by Rockridge residents. In the Bay Area, the vast majority of suburbanites use cars to access BART. Transit trips involving park-and-ride do absolutely no good from an air quality standpoint. Our research also showed to some degree substitution effects. Our survey asked residents to record information on up to three daily trips as opposed to a full day travel diary. Residents from both communities average around two daily nonwork trips. However, a much higher share of these two' trips in Rockridge were by foot, suggesting residents reduce nonwork auto trips commensurately. We found that walking access trips, particularly to shops, were being offset by lower auto trips to nonwork destinations in Rockridge.

Lastly, in a more recent study, we conducted a similar investigation of nonwork travel for 50 Bay Area neighborhoods instead of 2. While comparisons of travel between two matched pairs might be illustrative, the results are always questionable in terms of their generalizability. Berkeley graduate students were hired over a nine-month period to collect detailed design and land use information for these 50 neighborhoods. For the 50 Bay Area neighborhood we had at least 20 household travel diary records, so there were enough data observations to say something about nonwork trips. Using factor analysis, we expressed variables by the 3D's— density, diversity, and design. Our study attempted to measure the existence of all of the things which are typically associated with transit oriented and pedestrian friendly environments for all 50 neighborhoods. The results of this study—in terms of how the built environment shapes travel demand-were mixed. The elasticities were very low. Once we controlled for income and other factors, marginal effect of density, diversity, design in explaining variations in non work trip rate and modal splits were fairly low. Several relationships were moderately strong, but for the most part once controls were introduced, it appears the 3D's exerted minimal influences.

While it is important that we can evaluate these relationships under current circumstances, we have to recognize that in an environment where we have incredibly cheap prices for motoring and parking, perhaps these findings are not that surprising. We should resist trying to write off the transportation-land use connection even when studies fail to show a big impact, The important question is: What would the effects of density, diversity, and design if we could get the prices a bit closer to what they should be.? Then we would likely be able to find much more elasticity. Another important point about non work shop trips is that really very little is known about multi-leg trip behavior, or trip chaining. A fair amount of shopping is impulsive. And what impacts are major changes in retailing having? While many criticize big-box as increasing auto dependency, people going to these places might actually be making fewer trips per month. Households need to make fewer shop trips per month when shopping at big-box and wholesale retailers. Such economic and lifestyle shifts are rapidly changing dynamics of travel behavior. We certainly need to be cognitive of such profound changes as we think about future research approaches to investigating the transportation-land use connection.

TRAVEL BEHAVIOR ISSUES RELATED TO NEO-TRADITIONAL DEVELOPMENTS — A REVIEW OF THE RESEARCH

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At first glance, it may seem odd to address telecommunications and land use at the same conference, but it actually makes a lot of sense. As Genevieve Giuliano noted they are in many ways about the same thing: providing more choices for people and expanding accessibility. Both topics have received a great deal of attention of late in the media and also from communities. In my own community, Austin, Texas, there is a lot of talk about both of these strategies as a way to address .the growing congestion problems.

In my talk I will address what we know about how urban form influences travel behavior, but it will be as much about what we do not know as about what we do know. I will review the different kinds of studies that have been done, some of which have been mentioned by other speakers, and comment briefly about what seems to be emerging from those studies in terms of what they suggest about urban form and travel behavior. I will then outline the many kinds of questions that remain to be answered, and will end by reflecting on whether or not we are even asking the right questions, or whether we should be thinking about the relationship between urban form and travel behavior somewhat differently.

Most of the recent research in this area falls into one of three categories. The first set of studies are simulation studies. These studies use traditional transportation models to compare different street networks, or different layouts'of land uses in terms of their impacts on travel. These studies do not empirically show the relationship between urban design and travel behavior, but they can be suggestive of the potential of urban design to shape travel patterns. These studies have focused on strategies such as transit-oriented development and rectilinear street grids.

The next set of studies I call aggregate studies. At the aggregate or macro level, studies look at differences in travel patterns between different types of communities. Perhaps this level of analysis is sufficient to enable planners to incorporate land use into our transportation models. The third set of studies addresses the micro or disaggregate level and explores how urban design influences individual choices about travel. These studies begin to get at the underlying mechanisms which explain how people make choices about travel and how urban design influences those choices. It is the micro or disaggregate level where we should -focus our research efforts if we are to fully understand the underlying causality in travel patterns observed at the macro or aggregatelevel.

Aggregate studies typically involve cross-sectional comparisons of different types of neighborhoods and focus on average travel characteristics for the neighborhood. But there are important differences in these studies in terms of how urban form is characterized. Some studies use simple classifications: traditional pre- World War II neighborhoods versus conventional or typical post World War II neighborhoods. In some studies urban form is measured in a variety of ways and these measures are factored into the analysis of travel patterns. The studies also differ in terms of what aspects of travel are analyzed, whether it is total travel, or work travel, or nonwork travel, or whether it is trip frequency, trip distances, mode split, or total travel. As a result, these studies are not all necessarily approaching the problem the same way or testing the same relationships. My very crude simplification of what these studies show give an indication of the consistency of the results: less total VMT in neighborhoods with higher density and better transit access; less VMT and higher percentages of nonauto modes in neighborhoods that are more pedestrian oriented, higher density, transit oriented; higher percentages of transit use and other nonauto modes for all trip purposes in traditional neighborhoods versus standard suburban neighborhoods; higher percentages of transit use for work trips in some transit neighborhoods relative to automobile neighborhoods. Together these studies suggest a consistent pattern of less automobile travel and more transit use in traditional kinds of neighborhoods at least potentially. But what these crude simplifications mask is the complexity that begins to emerge from of some of these studies. For example, in some of these studies not all of the urban design variables are significant, and others show that combinations of variables must be considered. One of Cervero's studies, for example, shows that the regional context is important in explaining travel patterns and that the character of the neighborhood is part of the explanation-you cannot just look at the neighborhood. These aggregate studies begin to suggest that the relationship between urban form and travel is more complex than it may seem on the surface.

Disaggregate studies, by contrast, analyze the travel behavior of individuals or households within the neighborhood in an effort to better understand individual travel choices and the role that urban design plays in individual choices. A better understanding of the mechanisms underlying individual choices will lead to a better understanding of the causal role that urban form plays. Typically, the analysis in these studies involves analysis of variance techniques which compare the variation within a neighborhood relative to variation between neighborhoods. Some of these studies use regression or logit models to compare the relative influence of different variables. Again, my very crude simplifications of the results of these studies suggest a pattern: more walking, but not necessarily less driving, to shopping for residents in traditional neighborhoods; lower time spent traveling for work related and nonwork related trips for residents in neighborhoods with higher accessibility; higher percentages of nonmotorized trips for residents closer to the bus or rail and higher density neighborhoods; higher percentages of nonautomobile trips for work and nonwork for residents in traditional neighborhoods; more walking to shopping and potentially less driving to shopping for residents in some traditional neighborhoods. Again the bottom line seems to be this pattern that there may be less driving, more walking, and more transit in traditional kinds of neighborhoods.

But these disaggregate studies reveal even greater complexities than did the aggregate studies. It is almost like peeling an onion: as each layer is peeled, another layer is found . The more research we do, the more questions we find, and the more we discover that the link between urban form and travel behavior is much more complex than we thought. One complexity that emerges is the trade-off between trip frequency and trip distance; if distances are short you may make more trips. Another complexity is the importance of the neighborhood context, not just how the -neighborhood is designed, but what surrounds the neighborhood. Yet another complexity is the importance of attitudes about travel and urban design and other matters as well. Typically these studies have produced relatively low R squared values, on the order of .20 to .25, which suggest that these models leave most of the variation unexplained, suggesting that there is still much that we do not understand about travel choices' and the role of urban design in travel choices.

So, although the research suggests that automobile use is lower in traditional neighborhoods, it also suggests there are numerous questions we need to answer before we fully understand why, or even before we can be sure. that the patterns that we seem to be seeing are truly meaningful. The first question is: What aspects of urban form influence travel choices. We see differences in traditional neighborhoods versus standard suburban neighborhoods, but what is it about traditional neighborhoods that is leading to the differences in travel choices that we see? This question must be answered if our research is to help-guide land use and urban design codes and policies. More, detailed kinds of research are needed to help determine what it is about urban design, what specific characteristics or sets or characteristics, lead to the observed differences in travel behavior.

Another important question is how to measure design. The simple answer is that it should be measured in terms of what really matters to people. For example, does it matter that it is a rectilinear grid, or is what matters the fact that distances are shorter and there are more choices of routes to get someplace? Is that what is important about a traditional neighborhood? Many studies focus on density, but is it density that matters? No, probably not. Probably what matters is what goes along with density: shorter distances to activities, better transit service, and other sorts of characteristics. Instead of relying on simple measures of urban form, researchers mus develop measures that reflect what really matters to people.

A third question is what aspects of urban form influence what aspects of travel. Different trip purposes are influenced by urban form in different ways: work versus nonwork trips, or different kinds -of nonwork such as shopping trips versus medical trips, for example. Different aspects of travel will also be influenced in different ways: the choice to make a trip, the choice of destination, the choice of when-to make a trip, the choice of what mode.

The relative importance of place characteristics versus person characteristics is another important question. What role do socioeconomic factors play in our travel choices? What role do attitudes and our experiences play? Are the observed differences between neighborhoods due to the people who live in the place ? A related question is the relationship between short- and long-term choices, in particular the choice about where to live. Are the observed differences in these neighborhoods the result of certain kinds of people choosing to live in certainkinds of neighborhoods? If so, it does not mean that there is not a connection between urban design and travel; it means that there is more of an indirect connection than we may think.

Another important issue is when people decide what they are going to -do, they decide based on their perceptions of the place and not necessarily what can be objectively-observed about a place. For example, one place may feel perfectly safe and comfortable to one person and not to another, and so their perceptions of the place influence what they decide about travel.

Adaptability and flexibility in travel choices leads to two key questions about the relationship between urban form and travel. First, does a change in urban form lead to change in behavior? If a city puts in more sidewalks or a new local store opens, will this lead to changes in travel behavior? None of the research so far addresses this issue directly. The second question is the possibility of substitution. If you walk to the store, is it in place of driving to the store, or is it in addition to driving?

A final question is whether or not there are geographic differences in the relationship between urban form and travel. Most of this research has been conducted in the San Francisco Bay area, or elsewhere on the west coast, although a number of recent studies have come from elsewhere. It would be interesting to see if the same kinds of patterns are observed in different kinds of places.

Why haven't researchers answered these questions or even gone very far toward answering them? One problem is insufficient land use data to make more detailed analysis or to explore a variety of measures of urban form. But collecting this kind of data is time consuming and expensive. Travel data are also a problem, in that the these travel diary surveys include so few households within any one neighborhood that it almost necessitates primary data collection to get enough travel data for the few neighborhoods for which the study can afford to collect the necessary land use data. In addition, it is important to collect data designed specifically to address these questions: attitudinal questions should be included in travel diary surveys, stated-preference techniques might prove fruitful, and qualitative research could help to increase our understanding of these issues and of the underlying causality.

It is also important to reconsider the broader question this research is intended to address. We can use urban design to alter travel behavior. One of the assumptions of the new urbanism movement is that by designing a place in a certain way, we will reduce the amount of driving that people do. But mostly likely, we are not going to see very much change as a result of these urban design strategies because of limits on the possibility of changing individual behavior and limits on the possibility of changing existing development. Think about what we have out there that we are not going to be able to fix. Given these limitations, the prevailing expectations of what urban form can do are much too high. One issue is that we can not be sure that travel changes are always going to be in the right direction. In my research in the Bay Area comparing two traditional neighborhoods with two conventional suburban neighborhoods, access to convenience stores, which is much higher in traditional neighborhoods, was clearly linked to a much greater frequency of trips to these convenience stores, but not to a reduction in the number of trips to supermarkets. This suggests that residents of these traditional neighborhoods are making extra trips: they make as many trips the supermarkets as everybody else, but they also make these to convenience stores because they have that opportunity. At times, by enhancing accessibility and increasing opportunities, urban form policies may actually increase travel.

In a more recent study in Austin, of two traditional neighborhoods, two early modem neighborhoods, and two more recent late modem neighborhoods, we asked residents to think about the last time they walked to a store and speculate as to what they would have done had they not been able to walk that day. Most people in all of the neighborhoods said that they would have driven to the same location or some other location if they had not walked that day, suggesting that most of these walking trips probably substitute for a driving trip; if people, had not been able to walk, they would have driven. But some residents said that if they had not been able to walk, they would not have made the trip at all, suggesting that some of these walking trips are induced trips—induced by the opportunity to be able to walk to a store. So not all of the walking trips 'observed in traditional neighborhoods are substituting for driving; some of them are additional trips.

Another issue is that the changes that might occurbecause of urban design strategies are probably going to be small ones. In my Austin study 77 percent of walking trips to the store apparently substituted for a driving trip. Put that together with how frequently people make these walking trips: the highest case was a neighborhood in Austin where on an average residents made 6.3 walking trips to a store or local shopping area in a month. Take 77 percent of those 6.3 trips and assume a one-mile round-trip distance, which is probably generous for walking trips,. and that means that in this neighborhood 4.8 miles of driving are saved per month per resident because of that opportunity to walk to a store. Better than nothing, but it is not going to have a big impact on the overall travel in the region.

A third issue is that the regional context, often forgotten in research, may provide more opportunities that mean more travel. In my Bay Area work, I also compared trips to regional shopping centers for two neighborhoods in the Silicon Valley area with access to numerous regional shopping centers, and the two in Santa Rosa with access to only two centers. In the Silicon Valley neighborhoods residents take advantage of their better accessibility: they do not just go to the closest center, they go to, on average, three or so different centers over a four-month period, and they take more trips. Put that together with distances to these centers and it appears that in total these residents are traveling much more than residents of the Santa Rosa neighborhoods.

All these issues suggests that there are real limits on how much we can expect to change travel through urban design. Does that mean we should not be concerned with this question of how urban design influences travel behavior? I would say no, we just need to ask the question somewhat differently. The important point is that research on this question will help to show how design can provide choices to do -something other than drive. This means focusing on how design provides choices and not on how design changes behavior and looking at behavior not as an end in itself, but as a measure of the quality of the environment. If people are not walking, then it suggests that the opportunity to walk is not adequate in that place: if they are not taking transit, then the opportunity is not adequate in that place. This means flipping the question around and focusing not on a change in travel behavior as an end, but focusing on providing people with the choice to do something other than drive as the end.

It is easy to resign ourselves to the fact that people are going to choose to drive and that is the way it is going to be. But it is relatively clear that people value having other kinds of choices and we cannot simply assume that everyone wants the same thing. My studies, for example, consistently show that people walk and that they seem to like walking. In terms of strolling rather than walking to a store, there are not significant differences between the different. kinds of neighborhoods; everywhere you look, people are walking. This suggests to me that either the urban designers do not really know what makes for a good walking environment if residents walk in places that the urban designers would say are not good places to walk, or that residents are willing to overlook the negative aspects of their neighborhood because they enjoy walking so much, or some of both. When asked why do they walk, residents give numerous reasons: exercise, pleasure, walking the dog, walking to the store in cases where they have the opportunity. Very few residents say that they do not enjoy walking; it is something that people seem to value the opportunity to do. Surprisingly, some of the conventional neighborhoods had as high a frequency of walking to stores as some of the traditional neighborhoods. In places where urban designers would say nobody would ever want to walk residents are walking. If walking is something that people value, maybe researchers should be looking at how we can provide that opportunity for people. If they take advantage of it, great, if not, at least they have the choice. Let's not focus so much on how to change behavior, rather let's think about how to provide people with those opportunities.

TELECOMMUNICATIONS AND THE 'DEATH OF DISTANCE': SOME IMPLICATIONS FOR TRANSPORT AND URBAN AREAS

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I would like to talk about telecommunications and the 'Death of Distance', a concept I will, explain in a minute: Much of what I am going to say is based. on a paper "Telecommunications, Cities and Technological Opportunism" published in the *Annals of Regional Science* (1996). Should any of you want the full two-hour presentation, 'it is available in the journal version.

The Great Expectations

The first thing that we need to do is try to identify the major issues we should talk about, and I like to talk about the great expectations, many of which are nurtured by the media. Here we must mention "The Death of Distance", the cover story of The *Economist* (September 29, *1995).*

Distance does not play a role according to *The Economist,* and hence some 'great expectations' are envisaged. We can talk about a 'nonmobile accessibility' which is congestion free, pollution free, accident free, and dispersed urban settlements noted by the previous speakers. We can talk about a global economy, global cities, and global villages, and we can talk about the information or knowledge society, all those great expectations that would emerge as telecommunications become more and more commonplace. In my view if distance is dead, we need to ask the question whether there is still a role for cities, and if there is a role for cities, what are its implications for transport.

Some Definitions

A brief set of definitions is in order. There is sometimes a confusion between the terms knowledge and information. Information, is really the collection of bits which have some meaning to someone. Knowledge is the accumulation of information which allows us to make choices, unlike information. So information can just be a hard copy or diskette that has some information on it and that has a meaning for someone, but it is not really knowledge.

Another term is telecommunications, a set of technical facilities and services which allow us to communicate information electronically. Telematics is a marriage of telecommunications and information systems or computers. There was an alternative term suggested in the early '80s of 'compunications' that did not really catch on, and telematics which is originally French is widely used. Technology is a collection of hardware and services which are adopted by a society. A variety of adoption patterns are evident and diversity is the name of the game.

The issues

We hear, certainly in the media, and to some extent in professional discussions, about the spatial effects of telematics in the information age. There is much confusion about geographical scale in this discussion: the intra city scale, the regional scale, and the global scale; we need to be aware of it and be cautious about what we are in effect talking about.

I would like to present some approaches to the study of technology in the city. If we look at the literature from the 1960s through the 1980s much of the discussion was focused on the dichotomy between the dispersion and concentration. Will telecommunications bring about dispersion or dissipation of the city, or will they increase or strengthen concentration? It seems to me that this is really too limited a way to pose the question because there seem to be at least two intersecting processes. One is the dispersion/concentration dichotomy, primarily at the urban and regional scales, and the other is the globalization versus localization dichotomy which may take effect at all scales. The intersection between these results in a diversity of effects. What we need to do is not to try to find a generalization of what will happen or what the bottom line impact of telecommunications will be. We need to understand what are the factors affecting telecommunications' impact and what are the potential benefits and costs, which are likely to be very diverse. The concept of diversity will be repeated in my lecture.

The ultimate question that we face in the present context is:

i) How different will the urban world be, and what are the implications for transportation that we will need to cope with?

To respond to this question, some additional issues must be studied:

ii) What are the underlying assumptions in the debates concerning globalization, localization, and dispersion concentration effects?

iii) What are the social implications, who benefits from them and who loses?

iv) Are there any policy tools which we can wisely use in order to obtain the objectives that seem to be desired?

As researchers in the fields of transportation, technology and urban systems, I suggest that we also address the following two questions:

v) Should we expect a single impact of technology? As I have already hinted, we probably should not.

vi) Do we need a new research paradigm to study the impacts of telecommunication on cities and transportation?

The present context will not allow us to address all the above-mentioned questions.

What I am doing in this lecture (as in the paper I cited) is very much speculation. I have not done in-depth analysis and quantitative, empirical research in-these areas, so I can talk about an interpretation that I give to the extensive reading that I have done in this area. I also might try to be somewhat provocative in this session to feed or nurture the discussion in the next couple of days.

Let me very briefly respond to the last two questions and then go on.

I certainly think that we should not expect a single impact of technology, and as I have noted earlier, variety is the name of the game.

A very interesting question deals, with the. need for a new research paradigm or can we live with what we have. I would like to recommend a very good book, by Stephen Graham and Simon Marvin, *Telecommunications in the City.* It is an excellent review of everything that has been written in this area. They recommend a new research paradigm, or the need for a new research paradigm, claiming that previous research paradigms we held for studying urban structure and urban transportation do not fit the situation where telecommunications really introduces totally new notions of time and space. I choose to disagree with them. I think that the notions that we have, as I will explain, or the paradigms that we have to deal with these notions are sufficient, and that we do not really need to throw everything away and start all over. So let me try to answer in more detail former questions.

The Dispersion of the City

The city is basically a transport-based phenomena. City structure and transport technology have been married together since the days of the walking city and certainly since the introduction of the automobile that brought dispersal to suburbia. Telecommunications, along the same line, may bring about further dispersal, into exurbia. But what I find is that travel time is to a great extent a constraint on how far people are willing to go. People want to, or have to participate in urban activities such as work, maintenance, and leisure, and although we see much suburbanization going on, there is a limit to how far people are willing to go. I think Genevieve Giuliano referred to it this morning. On the one hand, they want the amenities of rural life styles, but they also want the opportunities offered by urban life, be it shopping, work opportunities, or leisure activities. So they will not relocate too far away from the city. The process of suburbanization was clearly facilitated by transportation technology.

Now we return to the question: will telecommunications change the city? The information age logic talks about the transition from manufacturing to knowledge and information, and from transportation to telecommunications. So we have a variety of tele-activities: telecommuting, teleshopping, tele-learning, telemedicine, and 'tele' what have you. We are talking about a variety of concepts that have emerged to describe this nonmobile accessibility: cyberspace, the virtual city, the rural wired society, or the electronic cottage, much of this jargon taken from the science fiction literature. The latest in this series is 'hypermobility'. So we have all of these notions of what is going to happen. Peter Drucker said in 1989 that within 20 years commuting to the office will be completely obsolete. Twenty years have not yet passed, but we observe little dissipation of the city. Some of the reasons are discussed below.

The Underlying Assumptions

Let us look at the assumptions that underlie the information age logic. I think that there are four assumptions which need to be discussed. One is the primacy of the information economy. It suggests that we are moving into an age of the information or knowledge society where everything will be information, and there is a substitution of information for material goods. We will not eat anymore, we will just consume information, and I will refute this assumption in a minute with the support of some numbers.

The second assumption is that of substitution of telecommunications for transport, namely that the more we consume information, the more we work with information, and use information for leisure activities, the more we can reduce the demand for trips, because the information can reach us by telecommunications and we don't need to travel to the store or the cinema and so forth.

The third assumption is that there is a ubiquitous supply of telecommunications. Truly, the dynamics are such that increasingly we have telecommunications available almost everyplace. But, it is not completely true, as the economics of telecommunications will preserve the spatial variation, in part in access, but more so, in quality. Urban centers will always have better telecommunication facilities than rural areas and the farther out you go, as the economics of telecommunications imply, suppliers are not likely to facilitate the same quality and quantity of telecommunication services as in areas of high demand density.

The last common assumption is that there is a prevailing preference for spacious living conditions over urban living conditions, again as Genevieve Giuliano has noted earlier, I am not sure how widespread this is but there is a clear preference for suburban living. The assumption implies that if given the choice, households will relocate in the periphery.

Approaches to Technology

Given these assumptions, we can take a supply-side view which is very much technology driven, looking at technology in the sense of a technological fix. We have a congestion problem, we have an air pollution problem, so let's telecommute and we will solve these problems. The notion held by many suppliers is that they have the 'technology to fix', and they often believe that supply drives demand. If we supply all of these facilities and services, we should expect a change in demand.

The demand-side view looks at cities as very complex systems. Aside. from economics, employment and transportation, cities have some other problems as well, such as the quality of the environment, poverty, crime, health,' congestion. The intensity of these varies from one place to another and over time. If we take a behavioral approach, and this is what I strongly recommend; and try to understand the behavior of households, the behavior of firms, and the behavior of political institutions, we would find that the ability and desire to use telecommunications, or other technological fixes to solve urban problems are not so clear. The introduction of new technologies into complex social systems and institutions is hampered, among other reasons because it is not clear that such fixes bring immediate remedy and change.

Cities will change very slowly because-they are very complex systems; they are a mix of activities. I think 'that Sassen has nicely stated that the global economic and the local social and political forces shape the cities, so it is not just the global economy that will-change the cities. 'The local political and social forces, very much localized, are as powerful as the global economic forces in changing cities. The city has multiple functions and a multitude of players, and hence no simple and fast changes can be expected. Evolution is more likely than revolution.

We have another view of the urban future and technology that is brought forward by architects, who play a major role in the town planning arena. Genevieve Giuliano has already made some comments about how architects view the world, let me continue in that way. Architects often'hold views of idealized design, of what can be or should be done in cities and they tend to overlook the politics of a location, they tend to overlook market forces, and they tend to overlook the slow changes in the tastes of people. Let me show you two architectural designs, one out of a 1922 story, "The Contemporary City," by Le Corbusier: There are high-rise buildings, the transportation system of surface vehicles is in underground tunnels, and what you see in between the buildings are airports, as he envisioned small aircraft as urban vehicles. This is one form of idealized design of what the transportation age will bring about and it has not materialized.

Likewise, the city design titled "The Plug City," by a group called Archigram, shows what the telecommunications city will look like. It is all connected with ultramodern structures. I have not seen those around, and they certainly do not fit what we have heard this morning about the neotraditional design of cities. So I am afraid that architects' views reflect what they think should be or would be nice; but not necessarily what conforms with the actual processes in the city.

The Persistence of Cities

If we try to summarize what I have presented up until now, the ideas of a 'virtual city' characterized by 'nonmobile accessibility' are nurtured from a number of directions. One is what we call the utopian futurism literature, which on the one hand is a science fiction literature, and on the other hand emanates from futuristic architectural images of the city. Another source comes from the notion of the 'dematerialization' of society. There is some very interesting evidence that in the aggregate materials use is declining, but it is declining in share not in quantity, and it is very important to make that distinction. Nevertheless, this notion is nurturing the virtual city concept. There are also many (industry) interests who suggest that the city will be different and that we need to invest in technology. The on-going process of globalization of the economy also often suggests major changes in urban structure. But, it does not necessarily mean that all cities will change and that such changes be of similar vein.

Sd, we may talk about the persistence of cities. I think that centrality and agglomeration economies will continue to play a major role. Being located close to other services, other providers of similar or complementary nature will continue to be a major drive in the location decisions of economic activities.

I would like to discuss briefly the production and consumption of material goods, and the concept of dematerialization as part of the notion of the substitution of information for material goods. In my view it is not taking place, and let me demonstrate this. I would go back to a 1968 paper by Wolman, published in the *Scientific American,* where he talked about the metabolism of the city. In an hypothetical city of one million residents, Wolman shows the material input and output of a city (water, sewage, food, refuse, energy, pollution etc.). He shows, for example, that 2000 tons of food enter the city and a similar amount of refuse leaves the city daily. Likewise, coal, oil, natural gas, and motor fuel enter the city, and leave it in the form of particulate matter and air pollutants, and so on.

So much of what is going on in the city is actually material change from one form to anqther and this will probably continue to. be so. Let me very briefly demonstrate this with a few more numbers. A decade or two ago, we heard that one of the outcomes of the telecommunications or telematics revolution would be the transition into the "paperless" society. That has not happened because simultaneously with the advent of telematics, the photocopying machines were invented and popularized. The photocopying process "prod&es" paper in the sense that it significantly increases the amount of paper consumed in conventional white-collar activities. The worldwide growth of paper production is much faster than the growth in population (some 4.6 percent annual growth in paper production). Paper is not just used for information., Paper is also used for packaging, but much of it, and I think an increasing share of it, is used for information. The idea that the information will be stored on magnetic media and inside the computers and that we will not hold hard copies does not seem to work; it was certainly a premature and wrong assumption or forecast.

Paper needs to be transported in cities. A quick look at freight movement statistics shows that goods movement has grown between 1950 and 1990 by roughly fifty percent in ton miles delivered, and that 'between 1960 and 1990 there was more than a threefold growth in urban truck vehicle miles. Much of it is, I think, the result of a rising standard of living. We consume more products and these products need to be transported from one place to another. Even if we use teleshopping, and do not travel to the store ourselves to pick up the goods, someone travels to distribute them to us and others. The vehicle mileage is still produced. Most probably, it may be done 'more efficiently than when we do it with our own private automobiles with an occupancy of 1 or 1.1. But then the question is whether by the rising standard of living and the quality of life that we want, do we also demand higher levels of service of the delivery system?

Do we expect and demand speedy delivery ? That may be counterproductive to the efficiency of distribution systems,

We should also. look, at some employment forecasts, as a preview to the discussion of telecommuting in this conference. We tend to think-that jobs are more and more footloose because they can telecommunicate. This is true in part for some jobs, but certainly not, for all. if we, look at the forecasts produced by the Bureau of Labor. Statistics (BLS). According to, a recent article, BLS forecast a growth in employment between 1992 and the year 2005, of a total of roughly 26 million people. Roughly half of them will be in the 30 largest growing (as opposed to fastest growing) occupations. Examining each of these 30 largest occupations in this 13-year period, we find that of the 13 million jobs in this group, 87 percent will be what we call "location dependent" jobs. I do not believe that within this period we will'have brain surgeons or nurses who telecommute. The largest growing occupations include salespeople who need to be in place in. the 'retail industry, registered nurses (3/4 of a million), cashiers, general office clerks, truck drivers, waiters, nurse's aides; janitors, and so forth—a very large, number of jobs which are clearly location dependent. The first occupation which is a candidate for telecommuting is system analysts and they are ranked in 10th place in the list of growing occupations. If you look 'at the grand picture for employment changes, we. are not in the right trend for more substitution of travel, but instead less substitution of travel. We need to consider the fact that the cost of distance of traveling will be quite persistent.

The last point that I want to make is the one of network flexibility and its implication for location. We are in a network society and. we tend to use the term of flexibility particularly in reference to telecommunications. But flexibility may not. be so simple a concept. We are a network society because we rely on water and sewerage networks, and transportation networks which include roads, rail and air networks, and telecommunication networks, of course. These, combined; have brought about the concept of the network society. Location decisions are very much- affected by'those networks; we cannot 'locate where we do not have water or where we do not have sewerage, so this is one constraint on our location. But the general belief is that the more flexible networks are, the more flexibility we have. in our location decisions; I want to claim just the opposite. True that-telecommunications are relatively flexible networks. We can literally put a university or a: research center in the middle of the desert and provide it with a satellite link and have all the information transported to them with no problem,, so they are very flexible.

The argument that I want to make is that location decisions are determined by the *least flexible* elements of the network, and I think that in the context of cities, the least flexible elements of a network are airports. The nodes of the airline network, which we cannot move or expand very easily because they impose certain requirements and constraints like land requirements, lead time for implementation and severe environmental impacts. This is one reason why existing cities will continue to flourish and telecommunications will have a very marginal effect, because it is the inflexible elements that determine location.

Technological Opportunism

Much of the great expectations of telecommunications and cities builds upon what we call the technologicaldeterminism school of thought. I do not believe that we should use or accept too much of this technological determinism. Jean Gottmann has said, "It all depends on what people decide to do with technology, it is a humanized or social technology." We should focus on the process and outcome of the adoption of technology. We should thus search for the alternative to technological determinism.

Telecommunications are a facilitator of change, but do not in themselves create change. The change in cities is generated by a variety of other factors which we have called location factors.

I think that we need to look at two different schools of technological "isms" as alternatives to technological determinism. We need to understand the concept of technological 'possibilism', whereby technology facilitates change, and the one that I like and would like to develop is that of technological "opportunism", the process by which agents seize an opportunity to use technology in a way which suits them well. Opportunists seem to be a relatively small group in society, so we are not going to see a major change.of urban cities, but we are going to see these research centers which are based on a hill in the middle of the Rocky Mountains or in other unexpected places.

The factors that affect the impacts of telematics on cities can be divided yet another way, by distinguishing between knowledge activities and information activities. This will result in another classification of types of cities.

Some cities are knowledge cities and they include university and research and development towns like Cambridge, Oxford and the Japanese Technopolis. They also refer to cities with major cultural centers and government centers, as well as world cities. There is a new term, coined by David Batten, that refers to network cities. We also have the information cities, where basically information is being processed but not where it is produced or consumed. Here we find back-office activities that we see in many cities, sometimes in the major cities, but very often in peripheral areas. They do the back-off& activitiesof the information economy, and these appear at the urban scale, in some places we see the neighborhood with the back-office activities. But, also at the regional scale (and even at the global scale where suddenly the back-office activities are being done- in the Caribbean somewhere or in India) rather then close to where the information is produced and used. Due to the time constraints, I will not dwell on the two other types of cities.

Conclusions

What I am suggesting is that we should study the impacts of telecommunications (a facilitating technology) armed with the concept of technological opportunism. It may allow us to understand how big business and industry change from a single plant to the multinational; how governments deal with technology in different ways at different levels; and most importantly I think, how individual entrepreneurs exploit technology to reduce the costs of distance in location decisions.

Entrepreneurs find fantastic opportunities to develop activities which could not be done 10 or 20 years ago. My favorite example is of a software firm that is located in my own city in Jerusalem that works solely for the Japanese corporate market, producing software in Japanese in Jerusalem, (Salomon & Tsairi, 1995). Why? Because there was one young person who identified an opportunity and decided to develop this particular software house, where he desired to live (Jerusalem). Much of the communication between the market and the producer is by telecommunications, but they also need to travel on occasion. The need for face-to-face communications eventually led to the establishment of mutual liaisons, so there are some Japanese in Jerusalem and some Israelis in Tokyo. This case exemplifies the notion of opportunism that could not have been realized ten years ago. But does that mean that Tokyo will dissipate because it is running business globally? Most probably no. Tokyo will persist because the bonds holding it together are independent of telematics.

Telecommunications can be used by entrepreneurs in so many different ways and we will see more and more of it. We will not talk about the policy implications, but these should be a target of some studies, along with various other studies on the behavior of entrepreneurs in the face of new technological options.

In conclusion, cities depend on multiple networks and not just telecommunication networks, Technologies of transportation and telecommunication are complementary more than substituted. We need to realize that the dematerialization may be true in the aggregate, but there is a great and rising demand for material goods, and they need to be moved. Cities are much more efficient than dispersed settlements, and telecommunications open new options for very diverse applications. There is a growing role for opportunists in all this. We also need to remember that social processes are slow and thus urban changes are not revolutionary.

So if we go back to the opening statement taken from *The Economist,* that "suddenly distance no longer mattered", I choose to disagree. Distance is alive and well, but changing in character, stretching for some (opportunists), but persistent for others. Most of the cities that we are going to see will be very similar to what *we* have today. I *think* that what *The Economist* did was a premature pronouncement of the death of distance. Distance is staying with us.

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THE COMPUTER COMMUTER: NEIGHBORHOOD TRANSIT FOR THE 21ST CENTURY

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This conference is focused on the potential impact of telecommunications on the future. Today we have heard a great deal about the potential relationship between land use and communications. I want to present a concept I have been researching for the past four years. I am currently completing a'feasibility study to apply this concept in Bergen County, New Jersey. It combines the electronics of communication with small vehicles thereby allowing people to move easy and efficiently in the current sprawled urban pattern. It also provides an ideal transit mode'to enhance the emerging neo-traditional urban form, and is an ideal retrofit for small communities and rural areas that can't afford any type of transit. It is only possible today because of the current evolution of computer, communications and satellite technology.

The suburban dispersed, low density pattern presents a challenge to transit operators. A flexible new approach to transit based on neighborhood needs can change long-held commuting habits. Most people know what's wrong with suburban transit. Simply stated, it does not go where people need to go when they need to go. In our (staff at ANA) informal observations around the country, the average number of people seen riding publicly subsidized 54-passenger vehicles at all hours of observations is five; Most school buses for upper grades operate at an estimated 15% efficiency rate, a tremendous waster of energy and resources.

There are five reasons that account for the failure of suburban transit: sprawled low density land uses, pricing, insufficient route and schedule information, Americas' dependence on the automobile and the negative images associated with transit.

Sprawl

Traditional fixed-route/fixed schedule transit was designed to serve the hub and spoke urban forms that characterized the 19th-century metropolitan development. Since World War II, however, development has shifted population out from the cities to the suburbs in dramatic numbers, and, as a result, automobile ownership has increased steadily while the VMT of vehicle miles traveled per person has increased even more dramatically, particularly in the past few years. Most suburban households have two cars, make ten or more trips per day and have an average commute of 27 minutes and pay approximately $5,900 per year to own and operate a two-year-old car according the American Automobile Association.

It is not difficult to understand the "affair" with the car-in human terms, when the most popular new vehicle sold in American is a small plastic car/walker, typically given to two year old children by grandparents. Combine this with transit deprogramming of early teenagers at fourteen, when the ubiquitous yellow school bus becomes the "loser cruiser." This programming indicates how serious an image problem transit currently has for potential future customers. This image must be overcome by presenting a more positive image of transit. Our focus groups have indicated that we must and can improve both the functional and operational characteristics of transit, thereby attracting more customers.

Thus, there is now general agreement that, except for older urban centers and neighborhoods, most metropolitan areas are characterized by distances that are too long, origins and destinations that are too dispersed, population densities that are too low, stops that are too far away to walk to, and land uses that are too separated to enable fixed-route transit to compete for transportation trips. In fact, transit currently accounts for only two percent of all trips and most of that is commuting to work.

Attempts to respond to this dilemma-park and ride lots, HOV (high occupancy vehicle) lanes, carpools, van pools and feeder shuttles generally have not succeeded in motivating commuters to leave their cars behind. The only way many analysts now see an improvement in transit status is by radically changing travel behavior, life style, energy costs, and land use development policy to end sprawl thereby making transit work again.

The impetus to avoid the sprawl pattern that characterizes post-World War II America has received a great deal of attention in the press over the past few years and reflects many of the ideas of a growing group of planners, architects, developers, and traffic engineers, all called "New Urbanists."

This group has identified techniques like TOD or (transit oriented development) and have adopted successes like the LUTRAQ project in Oregon. Under LUTRAQ, 33% of work trips generated by TOD's would be by transit, or by foot or bicycle because new walkable mixed use neighborhoods will be connected together with light rail and bus.. New urbanists also focus on reviving modified grid street patterns and building more compact, walkable communities with a mix of housing and jobs; retail, civic uses and parks in which car use is made less necessary.'

One vision shared by the New Urbanists calls for walkable communities served by light rail which links other compact, mixed-use communities. However, TOD is not simply aimed at increasing transit patronage; rather, its proponents assume a significant interaction between well-designed pedestrian communities in which it is possible to walk to schools,, parks, recreation, jobs, and transit stops, helping to shift attention; away from land use density as the only factor affecting transit. The problem is that light rail-is extremely. expensive. The stops must be designed for an optimum walking distance similar to thatsupporting bus service, and requires high densities.

In fact, land use changes alone cannot solve the current suburban transportation dilemma. Not only does that approach make untenable assumptions that customers should adapt their lives to the needs of transit rather than vice versa. It also fails to account for the existing low density development patternacross America. What is needed, instead, is a fundamental redesign of the metropolitan transportation model that would eliminate transit's 'linearity and dependence, on land use densities for service efficiency. A transit system that could begin to nurture the, sense of neighborhood in typical sprawled housing developments and even could adapt to changes in climate.

Pricing

Economists typically argue that commuters choose the car over transit because the automobile seems to cost less. This perception derives from the notion that public 'policy has subsidized drivers with tax revenues collected from non drivers, leaving the real costs of automobile usage unaccounted. for. A recent Planners Advisory Service report by Terry Moore and-Paul Thorsnes, however, maintains that drivers do in fact pay—either directly (out of pocket) or indirectly (through taxation)—for nearly 90 percent of the cost of the nation's automobile-dominated transportation system. Indeed, in suburban areas, the taxpayer and the 'commuter are the same person. Moore and Thorsnes calculated that when the direct costs, taxes, and externalities (air pollution, accidents, and public safety) associated with owning and operating a car are combined, drivers pay $7,000 of the $8,000 that an automobile based transportation system costs per vehicle per year. Given that slightly more than half of all, households now own two or more vehicles, many Americans pay in the range of $14,000 per year for automobile based transportation. It is difficult to believe that Americans do not realize how much they spend on automobile commuting or that they consider an expense of this magnitude negligible.

That Americans choose to pay more for driving versus transit likely points to the range of benefits not currently provided. by transit. Thus, trying to encourage a shift to transit by focusing on the pricing of automobile commuting may not yield the desired result.

Information Gap

Another reason for poor transit patronage in the suburbs is the lack of information about routes and schedules, and if there is a schedule it is often not accurate. As an example in the past year, due-to my recent move to a town I take transit to the university.some ten miles away. After nine months of bus commuting,. the bus. back. from theuniversity has been running an average of 14 minutes off schedule, ranging from one minute to 35 minutes late, leaving the most avid rider frustrated. Maps and schedules can be confusing to read and are often in short supply. Transit- stops are often poorly located or identified and perceived as negative in most Visual Preference Surveys™ I have 'conducted across. North America; (1 j Furthermore connections, fares and transfers between different forms of transit-such as bus to train-and even between different **lines** on the same system-such as one bus route to **another—are** often poorly coordinated. Routes are often circuitous and time-consuming: travel time for the'commuter to work by automobile has remained fairly constant at 25 minutes for a IO-mile' ride while it 'takes an average of 50 minutes for a 12-mile ride by bus transit. Finally there is the problem not often discussed in public that bus drivers may simply abandon whole portions of their routes so that, the bus never arrives at particular stops. Reliance on transit in the suburbs, no matter how. low the fare, often seems like a high risk proposition.

*(1) The Visual Preference Survey is registered trademarked of A. **Nelessen Associates of** Princeton New Jersey. An estimated 450,000 people have participated in a VPS. Participants are asked to rate **images from** + IO to a -10 based on **whether** they fed the image **is appropriate for** the location.*

Americans and Their Cars

For many Americans the automobile represents independence, freedom and the lure of the open road. Ironically suburban development patterns have reduced choice by making automobile ownership and driving a necessity and even a source of stress: According to one'of the Barbara Walters specials, people are now being treated for "road rage" a form of stress that is generated by drivers competing for space in traffic congestion. Traffic congestion and the need for wider roads continues to strain local and national resources, decrease air quality with some cities having very serious air quality problems and produce visual chaos. Again based on Visual Preference Surveys™, the typical American arterial has an average value of -5 and below.

Recent research into suburban transit suggests that suburbanites may be ready for change, especially if that change offers options that meet or exceed the automobile's benefits **in terms** of immediacy, convenience and comfort, access, reduced traffic-related, stress, improved': livability of communities, **and** substantial cost savings.

The Computer Commuter: Neighborhood Transit

Neighborhood Transit is an alternative transportation concept that would put service within walking distance of 100 percent of all origins and destinations, regardless of density, thereby capturing a greater percentage of local trips than conventional transit. It is a flexibly" routed/flexibly scheduled, point-to-point, on-demand system that offers suburban **commuters** something they have never before enjoyed: choice. It does not seek to eliminate. automobile commuting but rather works with suburban pattern and preferences, not against them.

Neighborhood Transit (NT) is immediately **distinguishable** from urban transit in its most obvious manifestation: its vehicles. NT's small buses are a cross **between a limousine and a van** and replace large buses, which are too massive and unwieldy to negotiate residential suburban streets and operate inefficiently when-only partially full. By contrast, NT's **low-floor** vehicles provide accessibility while reducing passenger boarding time and thus dwell time at transit stops;' Propane gas or electric buses, which are both quiet and nonpolluting, are especially appropriate for Neighborhood Transit. NT buses can be ergonomically designed with large windows, a ventilation system, personal lighting, and sound system.

The NT bus would, be demand-responsive or available “on demand.” What does “on demand?’ mean? The system as envisioned would work as follows: you dial 1-800-NDA-RIDE. The computer then asks, “What pedestrian precinct are you in?” and you punch it in. The computer next asks, “To which pedestrian precinct(s) would you like to go’?” You then punch in your response. The computer answers, “six minutes, happy to serve you.” In six minutes, a small bus arrivesat your Neighborhood Transit Stop. All you need is a map, which numbers the various pedestrian precincts. your and a telephone. This is all accomplished using GIS, GPS, Digital packet data, and new on-demand response computer programming. Many Americans today use small buses at airports to reach their rental cars. Notice that all these buses are now equipped with computers and are linked to several service terminals. At Hertz you can now rent a car with a GPS and computer mapping/directional finder in your car. Digital telephone in cars have been standard now for years.. The neighborhood transit simply applies this to small buses and cars which travel between point and point on demand.

Your privately operated neighborhood transit company provides the map, which is subdivided into a series of small, numbered circles or pedestrian precincts.. Each circle circumscribes a five-minute walk to a center or bus stop. When the bus arrives, you pass your credit or bank card through the reader located inside the door of the bus. You are billed monthly.. If you are a first time user the driver will give you information to enroll in the system and register your personal PIN number, further simplifying the access calling and billing of your account.

The information and communication technology required to operate and manage such a neighborhood transit system calls for a wide range of capabilities-from -monitoring vehicle locations to informing potential riders of the arrival time of the next bus to dispatching appropriate vehicles in response to demand to tracking reservations for’ regular users to accommodating a wide range of fare payment methods (including credit cards and bank cards). Dramatic improvements in the power, memory, and processing capabilities of computers, coupled with the development of increasingly sophisticated yet -user-friendly geographic information systems, scheduling programs, and communications technologies, mean that the capabilitiesof handling the complexity of NT now exist.

Reliance on state-of-the-art information and locating technologies alone will not make the system succeed, however. ‘Neighborhood Transit is also changing the way routes and stops are laid out. A key underpinning, of the system is public involvement in locating stops and drawing pedestrian precinct boundaries to increase community satisfaction with the responsiveness of the system and to tie transit stops to community planning goals. Stops are simpleand flexible. The most common stop is little more than a flag with a number and several paving blocks. Since there is little if any waiting time, no elaborate shelters are required, A further advantage is that” the stops can change location depending on weather; For instance in cold winters and the hot humid summers, the location. of the stop. can be closer that the typical five minutes apart. It is a simple matter to change the location of the stops on the computer and moving the flag.

Service Areas

A service area is defined as the area-within 25 minutes of where patrons live and where most, if not all, local trip destinations are located. This service area should be laid out to capture a significant number of all local trips with view toward meeting rider needs and expectations rather than only meeting cost-effectiveness criteria. Traditional vehicle-based concepts of headways (time between vehicles), corridor density, direction of service, and average speed have little meaning compared to such passenger-based performance measures as waiting time, ride time, ride quality, and repeat customers, There are no hard rules regarding minimum population, densities, mix of uses, or geographic characteristics for determining pedestrian precincts or service boundaries. In addition, service areas can cross jurisdictional boundaries, just as travelers do.

Two basic concepts govern the design of a service area. The first is time, which is more important than distance and, for many people, more important than cost: a service area is laid out so that the regional median trip time does not exceed about 20 minutes. The time required to traverse a service area should average no more than about 30 minutes. The temptation to increase service area size to make more cost-effective use of vehicles or to capture more potential riders should be stubbornly resisted. Multiple, even overlapping, service areas with a central dispatch center are preferable to enlarged service areas.

The second concept is diversity rather than density. Each service area should account for a mix of all important local destinations, including schools, shopping districts, recreation areas, religious institutions, employment centers, and local stops connecting to other transit routes. Surveys and focus groups of community residents, major employers, and shoppers should be conducted to determine origins and destinations.

The Pedestrian Precinct

The basic service unit in Neighborhood Transit is the pedestrian precinct, which falls into one of three size categories. The primary and most often used precinct type is a circle that encompasses 162 acres, which has a radius of 1,500 feet and equates with a five. to six-minute walk. A second type encompasses 230 acres elongated around a mixed-use core of about two blocks or 1,000 feet. Because such a core includes interesting diversions, people typically walk the extra distance, as they do in a shopping mall. A third precinct could he 500 acres with a dimension of one-half mile (a lo-minute wake). Walking distance can lengthen to 10 minutes when the destination is a school, work site, or commuter stop on fixed-route transit as long as the pedestrian experience is comfortable and safe. Once walking distances exceed 10 minutes, the temptation to get into a car and drive generally wins out. In addition to the above, special stops, typically at or near the front door, are located to accommodate buildings with over 50 employees. When locating the pedestrian precincts on the GIS, places of employment which include retail, offices, industrial, service and institutional uses are plotted first.

After locating the major employers, the three basic sizes of pedestrian precincts are overlaid everywhere on a map of the service area. The interconnection of the center points of the precincts then forms the basic Neighborhood Transit network. Located at the center of each precinct is a Neighborhood Transit stop center, which local users select. The primary design criterion requires that no residence, business, recreation, or activity center be more than 1,500 feet (a five-minute walk) from a transit stop., Stop-centers may take the form of traditional bus or rail stops, main streets, town greens/ playgrounds, corner stores, strip malls, libraries, parks, or any of a number of locallandmarks.

The transit stop centers must be attractively designed and identifiable through information-rich architecture that reflects neighborhood needs and preferences. They can range from the simple (merely a flag/sign) to the complex (with benches, shelters, bicycle racks) as long as they are sufficiently recognizable to encourage use. Stops should always be placed within an activity center-for example, near the front door of a busy office building or near retail shops-not at the curb of the arterial street or at the edge of a vast expanse of parking lot.

Research and experience have demonstrated that the decision to walk-and hence to use. transit-is influenced by the walking experience., Thus, the character of the walking routes to and from stops is just as important as the character of the stops themselves: pedestrian-friendly routes, connections, and enhancements are a necessity. Good sidewalks make good transit.

The pedestrian precinct -is also an important tool to define a neighborhood. Many of the existing subdivisions are not-neighborhoods. They have no center, focus or defined boundary. The overlaying of the pedestrian precinct with the NT stop may begin to define the center and therefore has the potential to help define neighborhood, over time creating a better sense of community.

Cost Factors

Neighborhood Transit competes for so-called choice riders in the marketplace. Its target audiences distinguish NT from typical public transportation systems, which provide subsidized service to nonchoice riders. Neighborhood Transit would compete in the suburban market by offering benefits that match or exceed those of the private vehicle, including time savings, convenience, comfort, advanced technology, quality, access, and even a sense of community. Since Neighborhood Transit could be used for all trips, not just 20 to 25 percent that are work related, and assuming suburban travelers are sophisticated and rational and will pay a fair price for transportation that meets their needs and expectations, Neighborhood Transit should generate sufficient revenues to be self supporting. Preliminary estimates suggest that if Neighborhood Transit were used between 700 and 1,000 times per year, personal costs would range from $1,600 to $3,000 depending on the distance traveled. This represents a significant savings ($2,000 to $6,200) per year for each automobile. This is particularly important to a family that now must have more than one or two cars. With the NT, your teenagers or the second wage earner or even all wage earners could use the system for most of their normal everyday trips. Imagine the cost savings if this NT could be incorporated as school busing. Your property taxes might even go down!

Research by 0. J Smith at the Oak Ridge National Laboratory compared operating costs of fixed versus flexible route transit systems and found that it is possible to maintain the same area and frequency of service by using Neighborhood Transit and still reduce annual operating costs by nearly 50 percent over conventional fixed-route transit. Despite a slight increase in personnel needed to operate a computer based information system, savings are achieved by permitting the computer to select the most efficient route among origin and destination nodes rather than forcing a vehicle to follow a fixed path whether or not it is needed. The estimated costs on the Bergen County Community Commuter range from $1 SO to $3.00 per ride. The cost estimates were based on a detailed analysis of all equipment and operations costs. Assuming the purchase of all new equipment, average operating and maintenance costs and an operating profit, it is estimated that the system will only have to be subsidized during the months of start up.

Conclusion

Neighborhood Transit is a practical concept that has evolved over the last two decades of technological ‘innovation. It offers commuters greater transportation choice in existing low-density, automobile-dominated suburbs. It also offers the opportunity to transport more people comfortably, thereby reducing impacts on street and highway networks, reducing parking requirements and decreasing air pollution and driving stress. Unlike regional transit, Neighborhood Transit- is not dependent on development density and does not require urbanization or redevelopment; rather, its central organizing principle is travel time. As claims on Americans’ time, money,, and mobility grow more and more pressing, Neighborhood Transit will make more and more sense. The growing trend in home offices and electronic commuting combined with the Neighborhood Transit indicate a high potential for a new type of neighborhood and community which, if properly designed, can be interesting and exciting to live in, be economically responsible, cost efficient and technologically connected.

HOUSING AND COMMUNITIES FOR A CHANGING WORKFORCE

DENYS CHAMBERLAND

Centre for Future Studies in
Housing and Living Environments
Canada Mortgage and Housing Corporation (CMHC)

Introduction

Good afternoon, it is an honor to be with you today. I would like to thank the conference organizers for providing me with the opportunity to share with you some of the results of Canada Mortgage and Housing Corporation's research on telework and home-based employment and explore with you how changes in the nature of the Canadian work force are impacting' the use, design, and regulation. of our housing stock 'and communities. I till take you-to Montgomery Village, Canada's first telecommunity, and introduce you to a couple who have set up their home-based business there. I will then discuss how home-based employmentis challenging past concepts of how Canadians use their homes and communities. I will conclude by. highlighting how home-based employment creates opportunities to design housing and regulate land use and home occupations differently.

Montgomery Village

I would first like to transport you to Orangeville, Ontario, a small, town about' 30 kilometers outside the urbanized areas of Metropolitan Toronto; 'Just outside, of Oraiigeville is Montgomery Village, Canada's first telecommunity. Montgomery Village is an innovative community that is, modelled after the traditional architecture of Toronto and integrates new urbanism principles.

The community integrates a variety of housing types, and efforts were made to preserve key natural features of the site by reducing road widths and increasing the density within the built area of the site. Set backs were reduced and'the grid patterns were reintroduced with parks, located at key intersections instead of being tucked away behind houses. Lanes 'were also re-introduced and garages placed in the back in an attempt to reinforce the public nature and pedestrian orientation of the street. Placing the garage on the lane also created the opportunity to locate an office on the second floor. Finally, state-of-the-art Integrated Services Data Network (ISDN) or mid-band telecommunications service and zoning bylaws that-permit most home occupations throughout the neighborhood help justify its title as Canada's first telecommunity.

I would now like to introduce Mary Devries, a resident of Montgomery Village, who is out with her husband Robert for their mid-morning walk. Mary and Robert are both home-based workers and run their counseling practice for 'couples in their new home in Montgomery Village. Mary and- Robert moved to Orangeville from High Park, an affluent Toronto inner-city neighborhood: They were attracted by a number of factors, including the affordable price of their current home-t hey mentioned that they could never have afforded a house that would meet their live-work requirements in their old neighborhood. Meanwhile, they did not want to move to a typical suburban subdivision with a two car garage sticking out in front and were attracted by the new urbanism features of the community. In fact,. they actively sought to develop a co-housing community, but were unsuccessful and turned their attention to Montgomery Village.

In Montgomery Village, they were able to work with the builder to customize their house to meet the needs of their practice. The original house plans, which called for an open floor concept, were modified so that the business areas of their home could be independent and physically separated from personal household spaces. The front door opens to an enclosed lobby which is directly connected to Mary's ground level office where she meets her clients for counseling. There is a staircase directly off the lobby leading to Robert's basement office which is right below Mary's. Restrooms accessible to clients are found on the staircase landing. All of the office functions of their practice are in the'front of the house. A full wall was added to separate the workspaces from the back of the house where they have a great or' family room and a kitchen overlooking their back garden. Special efforts 'were also made to provide adequate visual and acoustic privacy to their clients: They also planned to use their family room for group workshops for couples.

From Mary and Robert's perspective, moving to Montgomery Village has been a great success. From a broader planning and environmental perspective, we can use their situation to illustrate a number of issues. On one hand, their new home incorporates some'of the latest technologies for energy efficiency and is located in a more compact and pedestrian-friendly community. On the other hand, with 2,600 square feet this is the largest home that they have ever owned, even when they had children. They are more dependent on their car. They no longer have access to good, quality public transportation as a'result of moving to Montgomery Village. They must drive to shops and services which were within walking distance in their old neighborhood. Montgomery Village, like many other "neo-traditional" or "new urbanism" communities, does not have a commercial area despite ambitious original plans. The planned main street anchored by a regional high school and including a telework center'is unlikely to be realized as originally intended. Another aspect of Mary and Robert's new lifestyle is that they must complete the hour drive to go into Toronto at least once a week. 'Finally, while their clients in Toronto could easily travel to their office via buses or subway, their new clients in Orangeville must now drive to their office.

Home-based Employment and a Changing Workforce

Whether Mary and Robert's situation is representative of the broader population of home-based workers remains unclear. What is clear is that they are not alone.

Millions of other Canadians are making, freely or by obligation, professional and lifestyle choices that are changing the nature of the Canadian workforce. Telework, telecommuting and home-based employment have become important facets of this trend. As in the United 'States, estimating the' magnitude 'of 'these new work arrangements is fraught with 'definitional and methodological problems and challenges. The available evidence, however, supports the notion that home-based employment is an important and growing phenomenon within a changing Canadian labor market.

Restructuring of the economy, government and corporate downsiiing, increased outsourcing, improvements in telecommunications and computer technology, and the desire to balance work and home life are all changing the way labor markets function.. Statistics Canada estimates that the percentage of non-agricultural workers' at home doubled, from 3 percent to 6 percent, between 1981 and 1991. Statistics Canada also forecasts that the absolute number of workers for whom the home is the main location of work will increase to 1.5 million in the year 2001 froml.l million in 1991.

Considerable attention has been given to the impact of telecommuting on urban form and transportation. I believe that other forms of home-based employment.deserve at least equal attention. It has been estimated that home-based businesses outnumber telecommuters by a ratio of roughly '3 to 1 in Canada (Market Facts of Canada). Discussion of the opportunities of telecommuting, for housing and community planning therefore cannot be easily separated from the broader implications of other forms of home-based employment. This is particularly true if one considers that the self-employed and home-based business owners are not only likely to work longer hours than telecommuters, but are also far more likely to work from home on a full-time basis.

Another important reason to think in broader terms than telecommuting is -where new jobs are being created in the economy. Telecommuting is associated with traditional employee-employer relationships, often in a medium to large corporate environment. However, net job creation in Canada is increasingly occurring in the service sector, small businesses and among self-employed workers and less in Corporate Canada. Government cutbacks have in fact led to absolute job, losses in the public sector in recent years.

Another reason to pay serious attention to self-employment is demographics; Aging baby boomers should reinforce the trend toward home-based employment over the next decade. According to the 1991 Census, Mary and Robert are not alone. Workers over the age of 55 were more likely to Work from home (whether they were paid workers or self-employed) than younger Canadians. Juxtaposed against this trend is the fact that Canada is one of three countries,along with the United States and Australia, to have experienced a strong post-war baby boom. Not only' are baby boomers more numerous, they are also better educated than the age that preceded them. If past trends are a good indication of the future, aging baby boomers could then swell the ranks of the self-employed working from home over the next decade.

If you will bear with me for a few moments, I would like to venture outside my area of expertise to suggest why transportation planners should pay close attention to contract workers, the self-employed and home&based business owners. Randall Crane in a recent. issue of the *Journal of Urban Economics* suggested that more attention be paid to the stability of employment when studying commuting patterns. The few questions on transportation in our 1994 survey of home-based workers in Canada unveiled the most profound differences between telecommuters and other home-based workers. It was clear thattelecommuters usedtheir cars less and traveled much shorter distances when working from home: 'For other home-based workers the situation was quite different as they needed to attend meetings with clients and associates as well as purchase and deliver products. Forty percent reported using their cars more often and more than half reported using other modes of transportation such as taxis or courier services more often. I will close this short tangent into transportation by saying that I remain intrigued by these results and would be glad to hear from any of you who may be able to shed more light on this information.

Challenges for Housing and Community Planning

Increasing home-based employment challenges some of the foundations of Canadian post-war housing and planning. That is the exclusion of work activities from the home; the separation of commercial, institutional and residential uses within communities; and traditional patterns of peak hour traffic between the home and the workplace.

Results from CMHC's national survey of home workers confirmed that the division between home life and work activities is becoming increasing blurred.

Most home workers were satisfied overall with their current arrangements. However, many commented on the difficulty in separating their professional and personal lives and on the lack of social interaction when working from home. When asked how appropriate their current home was for work, common problems for respondents included work spaces that are too small, the lack of storage space, intrusions from family, neighbours or friends, inadequate phone lines and noise from outside their workspace.

It is worth noting that the incidence of problems was higher among those who live in smaller dwellings and in multi-family housing. In this sense, it is important to remember that working from home is not always done by choice. Recent in-depth interviews with home-based workers conducted by a Montreal researchers have unveiled examples of a darker reality to working from home. In one case, a single women has seen her book-recording business invade most of the personal living space in her 2 bedroom apartment. Not only does her office and recording equipment occupy 3 out of the 5 rooms available, but her associate and the actors that they employ to record the books must come in and out all the time. Meanwhile, she must hide her business activities in fear that her landlord would evict her if he ever found out. While this is undoubtedly an extreme-example, it illustrates that for some working from home is a necessity and not a free choice. When the home environment is unsuitable for the occupation, working from home may seriously impede upon the living conditions and quality of life of the residents.

The ideal workspace for the overwhelming majority of respondents to our 1994 survey includes a separate room for work with natural lighting and ventilation, visual and acoustical privacy, adequate storage and sufficient electrical amperage and outlets. Other options such as a separate entry from the street or a workspace in a separate building were important for only a minority of respondents.

While Canada's residential stock is relatively new and in good condition-close to 2/3 has been built since 1960—it was not specifically designed to accommodate work within the home. As a result, home-based employment is generating renovation activity. A substantial,

Houses on the Information Highway

Houses of the future will also. need to. provide for the computer and telecommunications needs of home-based, workers. An emerging area of opportunity lies in the wiring of homes and communities for the information highway. In the future, midband or broadband connections could allow home workers to have access to a broader range of services such as: video conferencing and video mail; training videos on demand; multi-media and interactive collaboration; interactive education;. and visual demonstration in real time.

Unfortunately, much uncertainty remains and many questionsare still unanswered for developers and building owners interested in wiring their buildings for the midband or broadband connections :

- How big is the market for higher speed services?
- What are the services of interest to tenants or buyers and how much are they willing to pay?
- What will be the killer applications for the future?
- Who will be the service and content providers of the future on the information highway?,
- Is wireless the wave of the future?
- Should they own the communications infrastructure themselves?
- Should they let an external provider-in Canada usually a phone or cable company-provide the infrastructure and hold the exclusive right on the contents and services to be provided? (at Montgomery Village, Bell Canada provided the necessary. infrastructure for ISDN service)

Despite these uncertainties, at least two new wired residential buildings have been recently opened in Toronto and Vancouver. In both cases, these are luxury high-rise condominium buildings catering to an affluent clientele. It can be argued that the provision of high-speed access to the information highway is more about marketing a high-end product than about revenue generation for the service.

The Centre for Future Studies recently commissioned a study on wiring multi-family residential buildings for the information highway. The emerging recommendation is that builders and developers should attempt to "future proof' their building with flexible wiring designs. At a minimum; a conduit system to accommodate future wiring as well as space for future telecommunicatioti closets should be considered.

A new field trial north of Toronto may provide us with more insights and help remove some of the uncertainty about the true costs and potential revenues of wired -buildings and communities.. New home owners will move next month into Stonehaven, an 'exciting new wired subdivision in Newmarket. Thanks to Intercom Ontario, a consortium of over 70 companies including Bell Canada and IBM, the residents will have access to full-fledged broadband services such as video-conferencing, video-mail, high speed access to the Entemet, video on demand, home automation systems and connection, to a community information bulletin board.

For the companies involved, this trial will offer the opportunity to monitor the-use of the information services by the various members of households who purchased a home in Stonehaven. Millions of dollars are being invested to answer some elusive questions: What does the average person want from the information highway and what piece of equipment-television, computer, phone or personal digital assistant—will be the gateways(s) of choice?

The Centre for Future Studies. has recently contributed questions to the baseline survey of new home owners and we hope to officially join the consortium in the coming weeks and be able to study how having access to all these services may affect the residents' uses and perceptions of their homes and neighborhoods.

Regulatory Reform

These innovations cannot be implemented and society will not be able to benefit from telework and home-based employment without an appropriate regulatory environment at the local level.' Without regulations that are sensitive to the local context-i.e. the inner city, older suburbs or new suburbs, it will be difficult to harness. the potential for telecommuting and home-based employment to contribute to broader land use planning, economic development and urban sustain ability objectives.

The opportunities lie in creating the appropriate regulatory environment for innovations integrating work within residential environments or, in the opposite situation, integrating residential spaces within what have been in the past primarily work or commercial environments.

Canadian cities have recognized these opportunities and different land use regulations to accommodate live-work occupations are emerging for inner cities, older or new suburbs.

City of Toronto

The City of Toronto has recently launched into a bold zoning experiment to help revitalize two mixed use areas on either side of its downtown core: King-Parliament east of the downtown core and King Spadina west of core. These areas are diverse and lively and include a number of heritage and industrial. buildings as well as large tracts of vacant industrial lands. While these areas are stable and have solid employment base, the city wants to encourage increased economic activity in these areas, create new jobs and enrich the mix of uses. Part of its strategy is to attract investment to renovate many of the sound and attractive buildings in these areas into live-work units which would be attractive to artists, computer. programmers or other self-employed people.

To achieve its goal, the city is using a combinationof investment in community amenities such as public spaces and parks with a more performance-based zoning framework which is less prescriptive and provides for more flexibility of use. Out are density regulations, in are regulations focusing on built form; the height of buildings, their massing, as well. as light,, view and privacy standards.

Waterloo, Ontario

Home-based workers are also seen as a target market to revitalize older suburban neighborhoods further away from the downtown core or in smaller cities.' A study is currently underway in Waterloo, Ontario, to examine how the city's zoning regulations could be modified to encourage home-based businesses. One aspect of the study will examine how outbuildings could be added to existing ground-oriented residential properties.

These separate structures could be similar to garden suites, also known as granny flats. The concept of garden suites is not new. It has been marketed for some time as a means of providing independent living for elderly parents or relatives by installing on a semi-temporary basis a manufactured suite. The unit would normally include a bedroom, living room, bathroom and a small kitchen.

What is new is the intended use of garden suites as a workshop or office for a home-based business. For the home-based worker, the arrangement would offer the benefit of having the office or workshop located on the same lot, but in a separate building from the residence. While the intent is to keep the character of residential areas, the project proponents hope that attracting a critical mass of home-based businesses within a neighborhood adjacent to the city center would create opportunities for networking, to share services and to walk to appointments.

Markham, Ontario

Regulatory reform is also underway to encourage home-based employment in many suburban communities across Canada.

In one example, the town of Markham has adopted a new "blanket" home occupation bylaw. Instead of focusing on which home occupations were permitted or forbidden, this so-called blanket bylaw permits home occupations, with a few exceptions, as a secondary use within ***all residential zones*** of the town, provided that the business activity meets a number of performance standards related to: the size and type of home business; the number of employees; retail sales; the noise level; signs and parking.

Conclusion

In conclusion, telework and home-based employment are part of larger changes in the nature of work in Canada and can be expected to grow in the future. Telework and home-based employment will continue to change the way we will use, perceive, design and regulate our communities. It will require renovations and adaptations to the existing housing stock to meet the needs of home workers. Moreover, new flexible, adaptable and innovative designs. will be needed to meet the diverse needs of this changing workforce. Finally, the challenge for cities will be to make the necessary adjustments in land use plans and regulations to unleash the potential for telework and home-based employment to generate economic growth, revitalize neighborhoods and improve the quality of life of citizens.

CLOSING REMARKS: IMPLEMENTING NON-TRADITIONAL SUBURBAN DEVELOPMENTS

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Thank you, I really enjoy the opportunity to be here. It is a delight and I was honored to be asked. I am going to address the topic today from the perspective of the developer, one who is a practitioner, who puts thoughts and ideas into place and deals with the marketplace. Development is something my company-has been involved with for the past 25 years, and I direct our community development division. We are active in doing large-scale planned communities throughout the country—suburban development-sprawl,. if you will. I want to begin with the definition of a developer. I say the developer is a guy who was born in a municipal hospital; educated in public schools; attended a state university on an ROTC scholarship; went to graduate school on the GI bill; started his company with a loan from the Small Business Administration; gets his capital from federally insured banks; sells houses through FHA loans; does commercial development through county industrial bonds; does some rehab through tax credits; and then goes into politics and complains about how we need to get government out of our lives! Developers are actually purveyors of goods. Developers are blamed for a lot of our growth problems, but they are in fact just responding to a market. Developers do not go round people up and kidnap them in Michigan and haul them off to Arizona and force them to buy houses. The developer is providing a service in the same fashion as the butcher and the baker and the candlestick maker; he is responsive to a market. Where there is no market, there is no development; Where there is a market, there is lots of development. The problem' with development is, ofcourse, that it impacts the public at large, and leaves a mark on the landscape. So there is a very necessary public involvement in that process. One of the many myths is that it is development that has produced all of the traffic congestion and transit problems we face today.

Talking about what we face today, I thought I might begin with a bit of historical perspective. Because I am a historian by avocation, I think it is important to understand how we get to places, and you do that by looking back a little bit. We think that the design, development, transit, commuting, and traffic issues that we are facing today in the middle. of the 1990s are fairly recent in most respects. I would say that they were evolved in the last half century from an unusual source.' It was the Russians! Why the Russians? Because as a result of the Cold War, and as the result of the conflicts of WW II and Korea, and the threat of spreading Communism in the early 1950s, this country undertook to develop the Interstate Defense Highway System.' Everyone forgets that "defense" is in the official title in that term. The concept evolved by General Lucius Clay; under the direction of President Eisenhower, was to come'up with a national system of roadways suitable for moving troops and equipment in time of war and for the evacuation of our major population centers. That was the whole point behind it all. Pursuant to the law of unintended consequences, 'however, it had a completely different result in the context of its impact on our society, and certainly impact on development and on transit. The highway law was signed on June 29, 1956, and within 18 months a huge road-building boom began all over the country. For the next dozen years, we built interstates between cities and beltways around cities, but we also built peripheral roads and feeder roads to access these interstates and beltways; and the road transit system we are familiar with today came into being then, all this was essentially within the last generation.

The impact of that transit system was remarkable. What did it do? The first thing was to cause people to start moving to the suburbs in volume. The evidence of that, I think, can be traced by looking at the composition of the Congress. In 1960 we only had 57 districts out of 426 House districts that were characterized as suburban. In 1970 when the country did redistricting pursuant to the census, that number had doubled to 130. Between 1970 and 1990, it nearly doubled again to 2 12. Today essentially half of the House of Representatives is representing suburban districts. That is evidence of how the population has shifted. People shifted from the city to the suburbs, and how did they get there? On the Interstate Highway System. As this transition began principally in the 1960s and continuing through the 1970s, the retailers were quick to follow. Again, just a purveyor of goods following his market. By 1990 no one was in the inner cities anymore.

But as recently as 1970,. just 25 years ago, the major retailing centers were still in the center cities. In Washington D.C., you had Garfinkels, Woodward, Lothrop, and the Hecht Company and they were all downtown. In Denver you had the Denver Dry Goods, the May Company, Daniels, and Fishers and they were all downtown. Nordstrom was in downtown Seattle and only in Seattle. That was true throughout the country. But as everybody moved to the suburbs, the retailers picked up and went with them. By the 1970s you started to see suburban shopping centers as a distinct pattern of retail development, with all of the retailers picking up and following their market out to the suburbs. The employers were not far behind. They said, "Everyone has gone to the suburbs, we guess we will go too." And so, starting in the late 1960s but dominantly in the 1970s and aggressively through the 1980s, we began to see suburban office development, office campuses, and ultimately the emergence of the edge city.

This trend to suburban development and the emphasis on the automobile and the consequent development patterns are thus a fairly recent phenomenon. A prior speaker pointed out that all of this came about because of a consensus of public will, because the generation making these determinations and controlling these factors at the time was the Depression Generation. The Depression Generation favored roads and they favored suburban growth. There was no public opposition to this, and I think that a lot of people just did not see what was coming. What was coming and where do we find ourselves today? Today we find ourselves facing traffic and gridlock and continuing sprawl and all the impacts that these have on our society, and all the impacts, adverse as well as positive, on our culture as a whole.

There was a lot of discussion of this over the last couple of days, and in eavesdropping on the various sessions, I have heard commentary about where the blame for all of this lies and how this came about. I think there are some myths out there. In my capacity as a trustee of the Urban Land Institute, I was involved a few years ago in an extensive research project that we did trying to address transit in particular and some of the myths associated with suburban growth and suburban transit. One of those myths was-that the problems we have today derive from the lack of planning.. We countered that myth and said that is really untrue. Thereactually has been quite a- lot of planning; many people at this conference, have beeninvolved in that planning. The problem has been that there was a lack of execution. In 1802 Napoleon said "everything is in the execution" and that is as true today as it was then. A conference participant commented the other day that it is about political will. And, it is about political will. There have been many master plans, good roadway networks, transit and commuting networks, and concepts for developmentthat have been well planned in the past, but they have never been implemented. I know that in Northern Virginia, where I live in Leesburg, there is a very heated debate about the infamous Western Bypass or the new North-South Arterial, as a lot of people are startingto call- it, because the onus of the word "bypass". It has been pointed out repeatedly that there were very sensible road systems to address this need that were put on paper back in 1963, over 30 years ago, but nobody ever implemented them. The local political jurisdictions never addressed the plans, they let them lay-fallow. So today when you try to do it, you have battlesbetween jurisdictions over alignment, this county wants it this way, that county wants it that way. People who have moved into the jurisdiction do not want it at all. People who have been there all along want it in a different place' than it is contemplated. So, the traffic and transit patterns continue to become congested, and we are making no progress. But certainly not for lack of planning. It was planned for and well planned for.

Another. myth is that we can solve these issues (and this one is dear to my heart) by stopping development. (That's always a solution,. aha, the developer, he's the guy, it's all his fault, let's blame him!) Just stop development and we will not have transit problems anymore. That is-also untrue, and is not true for a variety of cultural reasons. The myth is that traffic is increasing as a function of development. The fact is that the vehicle population and thus traffic, has been increasing as a function of change of lifestyle which has occurred in our society over the past generation. In Virginia-the vehicle population in the 10 years between 1980 and 1990 increased at a pace 65 percent faster than the people, population. From that you deduce that if we sent the cadets from VMI out to man the bridges of the Potomac, and not let anybody in, we would have had traffic problems anyway because the vehicle populations were increasing due to the nature lifestyle; kids driving to school, women driving to 'work, 'and the necessity to make several trips a day to shop, to get to the gym, and all those other family activities. So, it is not development. Development is not the cause in and of itself, and stopping development is certainly not a solution to the problem.

Another myth that evolved, and this is a historical one dating back to the '60s when these patterns were just beginning to evolve through the highway system; is that it is necessary to prioritize commutingto the center city. Unfortunately we still see tremendous amounts of public" money directed- at transit systems that are on the old hub and spoke system, and directed at commuting to and from the center city. Recent studies, however, indicate that the hierarchy of commuting is entirely different these days. Principal commuting is from one suburb to another suburb because the retailers and the employers and the people have all gone to the suburbs. You leave your suburban house to go to your suburban job, -to go to your suburban shopping center. There is very little suburb to center city commuting taking place.

The second priority in that hierarchy of commuting is from the city out to the suburbs; people who choose an urban lifestyle and prefer to live in the city find that their jobs have gone to the suburbs so they have to commute to the suburbs to get to their jobs. In third place in the commuting hierarchy do we find what everything has been planned for and funded for: the commute from the suburb into the city.

Another myth, and this is another favorite, is to not build the roads. If you do not build the roads, they will not come. I *think the* inverse of *A Field of Dreams* is *A Field of Insomniacs* because if you do not build it, they are going to come anyway. That has been proven through a number of examples throughout the country. On a local basis, in northern Virginia where I am based, I look at Fairfax City. A long time ago, Fairfax City decided it did not want to have growth, and did not want to have traffic, and they were going to do that by refusing to widen Route 123 where it transits the city. They would not acquire any right-of-way; would not put any restrictions on developing up to the old right-of-way line; they would establish all kinds of historic preservation districts to prohibit this., It worked as intended because they still have a two-lanemunicipal street going through Fairfax City, but you also have tens of thousands of cars transiting Route 123, causing all this congestion in Fairfax City. So not building the roads is also another myth. If you do not build the roads, that is not going to solve your problems.

On the other hand, building the roads is not going to solve your problems either. At lunch on Monday, Bob McCullough was talking about how youcannot build your way out of this. That is absolutely true. Anton Nelessen at the luncheon presentation on Monday made that point as well. He talked about the transit cycle, about how roads bring development, which brings cars, which bring a demand for roads, which brings more development, which brings more cars. That is sort of an endless cycle, and you can jump on that train at any point. To the extent that you do build roads to address the traffic problems, and you enhance the road patterns, you do create a demand for further development and it becomes an infinite problem. So that is the solution. From a developer's perspective and from an implementer's perspective, that is, these are the problems as we see them.

The issue is in how to address these problems and how we find solutions. One solution for the public sector is to put the solution on the back of the developer. Reference was made to. that at one of the workshop sessions I attended. We will have the developer, based upon all this statistical data, bear the cost of making improvements to transit systems that will be impacted by this new development. There are a couple of things wrong with this from my view as a practitioner. One is that a lot of that data is very skewed, and it is skewed intentionally, whether consciously or unconsciously, to find a funding mechanism to address these issues. Many of the databases which come up with formulas and purported solutions are very,, very faulty. In the end, it is not just the, developer that can solve the problem. There is this perception that the developer. is operating from a black hole in space. In fact he is not; he is part of the overall economic network

I would like to call this approach or putting the issue on the developer a "newcomer's tax". Anything that you get the developer to pay for is going to be translated into the cost of his project, and therefore into the cost that people have to pay when they buy into that project. It is really just a newcomer's tax. In any event, it is not the solution because the developer in making an improvement to a segmentof roadway that fronts his property is not addressing the congestion that might exist miles and miles away, even in another jurisdiction. This approach is clearly not a solution. There have also been a. lot of attempts to address these issues throughurban design. That was one of the topics of the discussions here for the past couple of days.., Urban design and how it fits into the equation in terms of addressing the problems and finding the solutions.

Frank Spielberg raised an interesting question.in the workshop yesterday. He asked 'if it is conceivable that subdivision and development ordinances and regulations are too restrictive. They do not allow enough innovation on the part of the development community. He even went so. -far as to say 'what if we did not have any regulations?" I would not, advocate that, however. Having no regulations for developersis like giving matches to pyromaniacs; there is no telling what you would get out of it. I will be the first one to tell, you that- no regulation is not a good idea In terms of regulations being too restrictive, however, absolutely! They are too restrictive. I cite as an example the 19th century village which is the little- town of Leesburg in northern Virginia in Loudoun County. Our county spent a considerable amount of time, and effort going through the development of plans and policies and ordinances that would allow neo-traditional development-a "new" 19th century village. When all was said and done, the regulations do not allow that.

I look at Leesburg where I live, and say that if I went in today as a developer and gave them a traditional plan and wanted to develop that way, they would laugh me right out of the planning office. The street I live on is only 1.8 feet wide; Well,, no one likes that, "cannot get fire engines down it? they would say. Well, we do, we have fire engines and ambulances and trash collection. vehicles go up and down that street. They would say that the lot widths are not uniform. That is true, lot widths range from 30 feet to 150. feet. They would say that the setbacks are notuniform. True again; we have houses built on that street early in the 1800s that front right on the sidewalk, and we have some built later that are set back,70 or 80 feet. They would say that your side yard setbacks are not uniform. That is also true. We have a few town houses that share a common wall; we have a few single-family historic detachedhouses that have a 5-foot separation, and we have others separated by 30 to 50 feet as a function of lot size. There is absolutely no uniformity. But what does that street have and what does that historic sector of the town have? It has amazing character; it hastremendous vitalityin terms of cultural diversity.

We also have tremendous variety in pricing. That is another issue that comes up, the pricing. Another speaker commented that when you start doing these plans, everybody gets paranoid because of the fear of putting a $125,000 house next to a $150,000. house. Well, I always cite examples like Leesburg, and say that in Leesburg we.. have houses on a street two blocks long that range in price from 3/4 of a million dollars to $100, 000. We have blue-collar workers, 'executives, salesmen, doctors, professionals; judges,: andclerks, and everybody seems to live together just fine. It is the diverse fabric of a neighborhood, and the fabric, of a community, and it all translates back into the product, and back into urban design. We have varying lot sizes, varying products, flexibility with the streets; Yet when this same county said, "Gee, that's a great neighborhood, let's reproduce it," they went out and created a set of subdivision ordinances and a set of development restrictions that basically prohibit you from creating it.

I am somewhat critical of this neo-traditional concept, and say there is not anything traditional about it. It is not even very "neo". The traditional component is that it is traditional, suburban subdivisions. There is no ability to reproduce a 19th century village. There is no ability to mix product. There is no ability to show creativity in street design and have interconnection between public spaces and residential units. So I think the answer to the question raised about the development ordinances being too restrictive is "yes". I think they are too restrictive. They are too restrictive because you would find-that responsible developers, in combination with creative urban design professionals, planners and engineers and architects, could come up with some terrific solutions to our problems and would really enhance our environment. But they cannot do it because we have a public sector side that is locked into a recently traditional mode: namely, suburban sprawl. That sector gets antsy anytime you propose anything creative. I think that is a significant view about trying to address these problems through urban design. We are going to have to see a lot more flexibility on the part of the public sector. And a lot more: creativity on the part of the public sector. That in turn will translate into alleviating some of the terribly restrictive elements we have on design now.

Telecommuting, of course, has been a topic of discussion the last few days. Telecommuting is touted now in many respects as a panacea: it is going to be great; no one will get into their cars when they can work at their kitchen tables. As practitioners, we do not see that at all. Telecommuting has yet to sort itself out in terms of impact on our whole society. One of the views I have on telecomrnuting is that it is not people working on their kitchen table, it is the ability to conduct your business from a variety of locations. When you look at it in that context, it certainly has impact and presumably positive ones, hopefully positive ones, but not what we are now thinking of. I think you will see, for example, that you will. have different commuting patterns because people will be able to do things at home in the morning: you do not have to go in at the rush hours between 7:30 and 9:00, you can go in at 1l:OO to 12:00, but the things you have to do for the first few hours, you can do with the modem, the fax machine and the telephone, so you can work out of the house. But you will eventually go to work. This will shift the commuting patterns, but it does not eliminate them. You still have to make the trip. One-still has to go from Leesburg to Tyson's Comer in Virginia. One still has to go from Point A to Point B in any major metropolitan area. People are just going to have the ability to go at different times, and more and more people will have, that flexibility.

I think that would apply as well in other aspects. Take people who ordinarily would leave on Friday afternoons and go to the local beaches here in Virginia or would leave and go down to Wintergreen in the summertime. Ordinarily we would see all those heavy commuting patterns on Fridays. I know that from Washington, D.C. to the eastern shore of Maryland on Friday afternoons is absolutely a madhouse. Traffic gets stacked up on Route 50, backs up at the Bay Bridge. Maybe we will start seeing changes in those patterns because people will be able to go on Thursdays; because on Friday when they get there, they are going to plug in and get online and be able to do a lot of work otherwise done in their offices on Friday: But it does not eliminate the trip. It just changes the distribution of the trips and changes the time at which they occur.

Telecommuting is also having an impact on office patterns. But again, not one that is frequently recognized. Everybody says that the conventional suburban office is going to go away and that we are going to have telecommuting which will significantly reduce the need for offices. In our practical experience, we are not seeing that. But we areseeing a change in usage. The standard office ratio was about 250 square feet per employee. That grew during the '80s to about 300 square feet because money was loose and times were good and so 'everyone got a bigger office, more space. That has now dropped to about a 200-foot level, and we think it will be under 200 feet, down to 150 - 175 feet on average. Why? One reason is because we see, particularly in the executive ranks, smaller offices but more offices, and shared offices. I was talking to a partner at E&Y Kenneth Levanthol, a national partner who travels a great deal. He made an observation about this. He said that they figured out that all the partners of senior rank, who had the traditional big 400 - 500 square-foot comer offices, did not need them. It was a waste of money, they were never there anyway. They were traveling all over the world, all over the country, to different offices, and were conducting their business through modems, telephones, faxes, and via Fed-Ex packages. They actually spent very little time in their offices. So they changed it. They cut all their offices down to 125 - I50 square feet. The people who are there every day are the ones who need the most space, not the executives who are traveling a lot. I have found that to be true in my own business (when Marty Wachs was introducing me, he commented on the projects I have in different parts of the country) and from my own personal experience I do not have a big comer office anymore. I have little "cubbyholes", as I call them. I have a little 125-foot cubbyhole in Virginia, an 80-foot cubbyhole in Philadelphia, and a 100-foot cubbyhole in Seattle. I move around to these different cubbyholes, and take the computer with me; the fax machine is on and you have voice mail to check-messages. You have a base of operations, but you do not need all that space. So telecommuting is impacting the character of offices, but it is not making suburban offices go away. No one is just working out of their house.

The statistics we saw from Canada, which have to be extrapolated to American levels, that Denys talked about yesterday showed that there was actually very modest growth in home worker employment. It has gone from 1.1 to 1.5 million, not a very large number in a country with a population of 30 million people. I do not think that telecommuting is going to translate into people working from home all the time and not going to work. It will translate into different work patterns and different commuting patterns. It will translate into a redistribution of office spaces, but it will not translate into elimination of office spaces. You are still going to need the office park; you are still going to need the parking that goes with it; you are still going to need the office space; but it is going to be reconfigured. The other view I have about telecommuting is that people go to work for reasons other than work. There was a prior comment made about that as well. I think Denys made a comment yesterday about how there was a lack of social interaction that had emerged in the studies of home workers. We go to work for team building. We are social animals, we go to work to meet our friends and have dialogue with them. We go to work for hierarchy, to get reinforcement that we have a value to an organization. We go to work for ego gratification. You get to walk in and everyone says, "Good morning, Mr. Boss." A lot of reasons we go to work do not have anything to do with work, and I do not think that is going to change. I think the cultural characteristics of our society are such that we cannot look at telecommuting as some kind of a panacea that will resolve all of our transit problems because everyone.is just going to stay home and get on-line and that is going to be the end of it.

I think the solutions are in a much more cooperative effort than we have seen to date. Michael Soffert commented in one of the workshop sessions that we need to see engineers, architects and planners working together more when it comes to issues of urban design and transit planning. I absolutely agree with that. But that group has to be expanded; you have to add to the engineers and the architects and the planners, cultural anthropologists and developers and elected officials. The elected **officials** have their hands on the throttle when it comes to development ordinances and implementation of policy. The developers are going to respond from the aspect of market constraints. We need cultural anthropologists to tell us some things about people and people's interaction that we may either forget or overlook. The solution is in more comprehensive discussion groups and more comprehensive dialogue, not unlike the one we have seen here for the past few days, but with an expanded audience.

I was sorry to see that we did not have more developers here at this particular session. I have in mind a cartoon from "Calvin and Hobbes." It opens with Calvin saying, "The more you know, the harder it is to take decisive action." Once you're informed, you see the complexities and all the shades of gray, and realize that nothing is as clear and simple as it seems, and in the end, knowledge is paralyzing. And it concludes by saying, "As a man of action, I can't take the risk of being informed." Maybe that is why a lot of developers did not come; they do not want to take the risk of being informed because they are out there busy responding to the market!

Those are some comments and views from a practitioner's standpoint, and I hope that it has been helpful. Thank you very much for inviting me.

INTEGRATING PEDESTRIAN AND BICYCLE FACTORS INTO REGIONAL TRANSPORTATION PLANNING MODELS: SUMMARY OF THE STATE-OF-THE ART AND SUGGESTED STEPS FORWARD

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I.-Overview

In the past several years, there has been growing public support for improvements to the quality of the pedestrian and bicycle environment, expressed in sharply higher investment in projectsencouraging of such travel; Many local,, regional, and state authorities are beginning to pay attention to how non-motorized transportation, can help address community problems with, traffic congestion, air quality, health, safety, and the vitality of neighborhood commercial areas. Intermodal Surface Transportation Efficiency Act (ISTEA) and the transportation conformity provisions of the Clean Air Act also have provided support for these local initiatives by providing funding flexibility and encouraging investments and policies that reduce the need for motor vehicle travel.

The regional transportation and air quality planning requirements established under these laws promote greater consideration and encouragement of non-motorized, travel options as part of Major Investment Studies, as well as in regional and state transportation plans and programs. In areas with serious air quality problems, the emission impacts of transportation plans and programs must be evaluated to assure contributions towards healthier air.

However, evaluating the effects of bicycle/pedestrian infrastructure and programs on travel behavior and emissions is in general a poorly developed science. Traditional travel demand and supply models for metropolitan planning have ignored walking and bicycles as travel modes. Little data have been collected on non-motorized travel and the factors that influence whether people find walking or bicycling to be a viable option. Hence, where bicycle/pedestrian projects have been evaluated, ad hoc techniques have been used, often without a good empirical basis. In most cases, these analyses have had serious deficiencies and have lacked sensitivity to multiple factors that are important determinants of travel behavior. This has led to serious mis-estimation of emission and travel impacts and frequently impeded adoption of sound plans and policies sought- by the public and a growing number of elected officials. Reform of these analytic techniques should be a high priority in the transportation planning and engineering community.

This paper reviews typical techniques in use today for estimating the travel behavior effects of bicycle and pedestrian facilities and programs and other factors that influence use of non-motorized travel modes and offers suggestions for near-term advances in the state-of-the-art and state-of-the-practice.

II. Current Modeling Practices

There are several principal approaches that have been used to evaluate the effects of transportation policies and infrastructure on bicycle and pedestrian travel. Some analysts have used regression analysis to relate aggregate travel behavior to other transportation and land use data. Others have used market-share diversion analysis to evaluate potential diversion of automobile trips to walk and bike, usually assuming varying modal diversion based on trip length, with fixed trip distributions. The third and most robust approach is discrete choice analysis, either based on aggregate or disaggregate data. In practice, inadequacies of both data and modeling frameworks have led to less than satisfactory performance for all of these methods in the American metropolitan planning context, although the latter approach offers the greatest promise for refinement.

Experience in cities such as Davis, California, and Copenhagen, Denmark, show that reallocation of street space and development of comprehensive cycling networks can have a profound effect in diverting car trips to the bicycle and that bicycle access can promote dramatic expansion of transit catchment areas. In Copenhagen, a city of 1.7 million people, road building was abandoned in the early 1970s, large numbers of bus priority lanes were introduced, and a comprehensive network of segregated cycle paths built. The result was a 10% fall in traffic since 1970 and an 80% increase in the use of bicycles since 1980. About one-third of commuters now use cars, one-third public transport, and one-third bicycles. Cycling accidents have decreased slightly, despite the increase in mileage, because of the network of cycle paths, which in many cases were created by reallocating arterial street space from cars. [1] Had Copenhagen embarked on major highway expansions in recent decades, surely energy use and emissions would be far higher than they are today. If the transportation models and methods common to most US. metropolitan regions today were used to evaluate the effects of Copenhagen's policies, they would not just underestimate the emission benefits of these policies, they would predict the exact opposite of the real world effect of these policies, producing dire forecasts of sharply higher air pollution emissions and traffic congestion.

The effect of restructuring street space in the' context of other supportive transportation and land use policies is not just a European phenomenon. Indeed, in Davis, California, the share of trips made by bicycle has experienced comparable growth in the same period in response to conscious public policy choices. Davis, California, a town of 50;OO0 people near Sacramento, illustrates a successful full traffic cell system which has cut highway capacity significantly in the vicinity of the University of California and town center to increase walk and bicycle use. Bicycle use grew sharply in the 1960s, leading to election of a pro-bikeway City Council in 1966. Demonstration bikelanes proved popular and were quickly extended. In addition to the UC Davis traffic cell and bicycle network, the City of Davis now has 37 miles of bicycle lanes and 29. miles of bicycle paths in an interconnected network. Parking is limited and costs drivers on the UC Davis campus. Bus, van, and commuter rail services offer other alternatives to the automobile. Davis has prohibited development of shopping centers near the freeway, retaining a vibrant pedestrian-oriented downtown commercial area. As a result, 27% of UC Davis employees and 53% of UC Davis students use bicycles as their primary commute mode. Of those who live and work in Davis, 44% bicycle to work. The City Planning Department estimates that 25% of all person trips in the city are by bicycle. Walk shares-in the city are also high--on the order of 10-20%. Clearly air pollution and traffic have been reduced by restricting and reducing highway capacity in Davis.,

Yet even with the best currently used approach to incorporating pedestrian and bicycle friendliness, into regional transportation models, the Sacramento regional travel model must include a, special geographic variable for Davis to match the observed use of non-motorized modes, which far exceeds what the model would otherwise predict. Clearly,. there is need for more research and model development to produce satisfactory analysis tools sensitive to the effects of factors influencing. non-motorized~travel. Untilthese are developed, airquality and transportation evaluation, congestion management systems, and community and regional planning work dependent on computer transportation models will .at best ignore or- underestimate the potential for reintegrating walking and bicycling into American communities.

A. Regression Analysis

The simplest approach to evaluating non-motorized mode potential is to use regression analysis against recent, aggregate data. An example of this approaeh is work done by a consultant to Pennsylvania DOT, which has since been adapted by CATS, the Chicago area Metropolitan Planning Organization (MPO), to Illinois. This.approach is characterized by.relating observed aggregate bicycle use data at the jurisdiction level (usually Census Journey-to-Work bike or walk mode share) to other aggregate variables, such as residential density, characteristic topography of towns, or metropolitan area. size. A presentation of this 'approach. was made at the 1995 Transportation Research Board meeting in Washington, D.C.

This highly aggregate nature of this approach makes it useful principally for first-stage research evaluating factors that may influence differences in travel modal dependencies in different regions. This approach is less useful for project or program evaluation, since it generally just describes the current gross patterns. of observed-travel behavior in different places:

B. Market-Share Diversion Analysis

This approach is characterized by evaluation of trip-length distributions by -mode and the use of analyst judgement to make assumptions about potential mode switching that might be induced by a policy/investment change. This approach can be applied in a more or less rigorous manner in defining the market potentially affected by a facility or:policy. Unfortunately, with this method, the sometimes questionable judgement of the transportation analyst can lead to poor estimates of program or project effects.

Several recent evaluations have used this approach. A typical case is work done by a consultant for the Metropolitan Washington Council of Governments (WashCOG). [2] Without supporting evidence, the analyst evaluating the Bicycle Element of the WashCOG Long-Range Transportation Plan assumed. that the plan would have no effect. on trip distribution and would produce no reduction in non-work vehicle travel, with only minimal diversion of work trips. [a] These assumptions were made despite the plan's explicit objective of producing a 5% mode share for bicycles in the year 2000. Applying a simple market-share diversion analysis, the analyst concluded the plan would produce a less than 0.15% change in total regional trips. It is not surprising that the resulting estimate of cost-effectiveness of this bicycle plan was very low, at $665500 per ton of Volatile Organic Compound (VOC) reduction. Not only were the estimated travel demand effects low-balled by completely ignoring non-work travel reductions and understating potential work travel impacts, but the same analyst assumed these facilities operated only 250 days a year and significantly underestimated the facility life at 10 years. Other analysts making empirically defensible assumptions different than these could estimate the cost effectiveness to be as much as twenty times greater. Unfortunately, this analysis was buried in a mass of other evaluations and the underlying assumptions went generally unquestioned. This work made use of simple graphical analysis tools and selected aggregate outputs from the regional MINUTP-based transportation model.

Another example of market share diversion analysis is work done by Stuart Goldsmith of the Seattle Engineering Department, [3] which is being used as a model by some other bicycle planners, for example in Portland, Oregon. This work evaluated a specific set of bicycle lanes based on the geographically specific travel market area they would affect, estimating the number of potential bicycle commuters using stated preference (SP) survey data on the number of people who said safer bicycle facilities would encourage them to bicycle commute. Non-work Single Occupant Vehicle (SOV) trips diverted to utilitarian bicycle trips by the bicycle lanes were also estimated using data on market shed, the share of residents owning bicycles, the share of these individuals using their bicycles forutilitarian trips, SP survey data on effects of safer facilities, and assumptions about modal substitution and trip length. This work has made use of spreadsheet software for development and implementation, complemented by data from the regional travel demand models, coded and implemented. in EMME/2. While more sophisticated than the analysis for WashCOG, this approach still ignores the potential for altering trip destination choice, synergism with other travel demand management strategies or even anticipated increases in roadway congestion.

As a quick analysis technique, this approach can produce reasonable results if the analyst makes appropriate assumptions, but it cannot easily account for potential changes in the spatial distribution of trip ends and trip length distribution that major changes in pedestrian and bicycle friendliness and other strong travel demand management strategies can induce, nor for changes in time-of-day of travel. Thus, this approach is destined to remain in the realm of sketch planning.

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[a] The analyst assumed at most a 10% increase in the share of Home Based Work walk/bike trips less than one mile, an 8% increase in the share of HBW walk/bike trips 1-2 miles length, a 4-6% increase for 2-4 mile trips, a 1-2% increase for 4-6 mile trips, and no change in travel for longer work trips.

C. Discrete Choice Modeling

This approach recognizes: the potential of walking and bicycling as legitimate forms of travel and seeks to integrate 'these modes into conventional regional transportation planning models. The best of these efforts have used indicators of pedestrian/bicycle friendliness along with fuller information on alternative regional transportation choices. In time, first stage qualitative indicators are being replaced by more rigorously measured quantitative factors, often estimated by use of geographic information systems (GIS); stated preference surveys, and other techniques.

In most U.S. cities, transportation models consider onlytravel time and cost of competing modes, ignoring the quality of the pedestrian and cycling environment and frequently treating the proximity of jobs and households to transit in at best crude manner. However, recent research and model development in several regions provides strong evidence that transportation modelers can improve their model's abilities to replicate observed travel patterns and behavior by including more indicators' of pedestrian and bicycle friendliness. Such. enhancement provides more defensible and policy sensitive analysis of air quality effects of transportation plans and programs than ad hoc methods used elsewhere.

A small but growing number of planning agencies in the U.S., Europe, and Asia have developed regional travel demand models that represent pedestrian and/or bicycle friendliness through qualitative or quantitative indicators, making these tools somewhatpolicy-sensitive to the potential, for improvements in pedestrian and/or bicycle facilities and related community design elements. These include the Maryland-National Capital Park and Planning Commission (M-NCPPC) in Montgomery' County, Maryland METRO, the regional government in Portland, Oregon; the Sacramento Area Council of Governments in California; and regional planning agencies in Sweden and Shanghai, China.

Montgomery County's Pedestrian Friendliness Index.. The M-NCPPC in Montgomery County, Maryland, a municipality of 750,000 people immediately north of Washington, D.C., in 1987 developed a Pedestrian and Bicycle Friendliness Index (PFI) as part of an AM peak hour work trip logit mode choice model. This index is a score independently assigned to all traffic zones in the region based on the availability of sidewalks, bicycle paths, and bus stop shelters, the extent of building set-backs from the street; and the heterogeneity of land use at a local level. [4] 'This index was found to be highly statistically significant and explained much of the variation in auto-transit mode choice not accounted for by another 'mode choice model which focused solely on travel time and cost factors, ignoring transit access conditions at the home and workplace trip ends. The index was used with travel distance data to develop a crude walk/bike mode choice model. This model was coded and run using the EMME/2 software package.

To reflect the likely effects of alternative pedestrian- and transit-oriented development scenario as part of the Montgomery County Comprehensive Growth Policy Study, M-NCPPC analysts made several adjustments to the model inputs. They assumed that in the most pedestrian-friendly central areas the PFI might increase above. the 'maximum level of 0.5-0.6 assumed to exist in the Washington, D.C. region in the late 1980s, to a future level of as high as

0.8. This was thought to represent a key part of the effect of possible traffic calming and development of limited automobile restricted downtown areas. Walk egress times in these areas were also increased from 2 to 5 minutes to reflect scarcer parking and automobile limitations. Automobile ownership levels were adjusted slightly downwards from 1985 levels in zones assumed to have much higher levels of transit, walk, and bicycle access in the future. This contrasted with slight further growth in household automobile ownership levels projected for a trend scenario. In evaluating the trend scenario, the PFI and automobile egress times were held constant at 1985 levels. The study concluded on the basis of extensive modeling and evaluation that the county would face unacceptable growth in peak traffic congestion if planned growth patterns were followed, even at slower growth rates, unless measures were taken to orient future growth around an expanded transit network, to improve pedestrian and bicycle friendliness, and to shift commuter subsidies and pricing policies to favor alternatives to single occupant vehicle travel.

To support initiatives to increase sidewalk construction and more fully incorporate the needs of pedestrians into transportation planning, the Montgomery County Planning Department (MCPD) developed a computerized geographic information system (GIS) database on side-walks. [5] These data have been used in the county's efforts in growth management, master planning, transportation analysis, and capital improvements planning. Until the development of the Montgomery County sidewalk database, there was only limited and fragmentary information available on where sidewalks existed and where they were lacking across the county. A 'quick and low-cost comprehensive survey, collected by two summer interns who spent 6 weeks driving on nearly every road in the county, provided raw data for the inventory. These interns marked up small-scale street maps with a dozen colors of ink to code each road segment for the presence or absence of sidewalks on one or both sides of the street, sidewalk width (under or over three feet), and the presence or absence of a buffer between street and sidewalk (of under or over three feet), and open vs. closed road sections. With this data, GIS software was used. to produce maps of roads by sidewalk status at various scales of resolution, as well as sorted listings of street blocks by sidewalk classification. The foundation of the database is the TIGER file used to enumerate households in the 1990 U.S. Census, a low-cost product available from the Census Bureau, which describes nearly all roads in the U.S. The inventory revealed that nearly 60% of the road links in the County have no sidewalks and only 37% of road links have sidewalks on both sides of the street, and that there is wide variation in the availability of sidewalks in different parts of the County. The sidewalk ratio was found to be a statistically significant factor in explaining whether people walk-to-transit, drive-to-transit, or drive a car to work, and is being used in Montgomery County's latest transportation forecasting models.

Portland METRO's PEF. A Pedestrian Environment Factor (PEF) is being used in transportation modeling in Portland, Oregon, by the METRO planning agency. The PEF was defined by local planners who scored each zone on a 1 to 3 scale for sidewalk continuity, ease of street crossings; local street characteristics (grid vs. cul-de-sac), and topography. These were summed to indicate overall pedestrian environment conditions, with scores ranging from 4 (poor) to 12 (good). The PEF proved to be a significant factor in determining automobile ownership, which itself is a powerful factor influencing transit ridership. It was found that in an area where walk trips can be more easily made, the need for an automobile is less. The use of the PEF also improved the ability of Portland's mode choice models to estimate walk and transit trips.

Residential and employment density and proximity factors, such as retail employment within one mile, enter into Portland's models separate from the PEE and are also important indicators of mode choice and automobile ownership. [6] This model was coded and run using the EMME/2 software package.

A major foundation and FHWA-sponsored study, "Making the Land Use Transportation Air Quality Connection," (LUTRAQ) developed and used this enhanced transportation model to evaluate a proposed western bypass highway around the west side of Portland, Oregon, vs. a transit and pedestrian oriented development alternative. This study showed that transit and pedestrian oriented urban design and infill development, and the retrofit of pedestrian improvements to automobile-oriented suburbs can have, significant effects, on travel behavior sufficient to eliminate the need to build new ring freeways, particularly when reinforced by sensible economic and pricing incentives, such as modest parking charges and reduced transit fares that begin to level the playing fieldbetween travel modes. Total vehicle trips per household in the TODs.were 6.05 per day, compared to 7.09 outside the TODs under the LUTRAQ scenario and 7.7 with either the Bypass or No Action alternative. The LUTRAQ scenario reduced VMT in the study area by almost 14% compared with the, Bypass, alternative and reduced Vehicle Hours of Travel in the PM peak hour by almost 8%. Even greater effects on travel behavior can be expected when these measures, are combined with bicycle improvements, stronger economic incentives, more effective parking management, introduction of neighborhood vehicles, and further shifts in land use policies to favor infill housing and commercial development. The LUTRAQ analysis indicated these Transportation Demand Management (TDM) measures accounted for about 30% of the increase in non-automobile driver mode shares for all trips and about 55% of the increase in non-automobile work trip mode shares, not counting the corrections for underestimated walk trips, which would further increase the effects of the design measures. [7]

The LUTRAQ model incorporated measures of pedestrian friendliness but underestimated the potential to shift short car trips to pedestrian trips., This was due to acknowledged under-reporting of walk trips in the 1985 Portland household travel survey data[8] and the assumption that nowhere in the region would pedestrian friendliness be, better, than it is today in downtown Portland (i.e. the maximum PEF was set to, 12). Clearly, Portland neighborhoods could become far more pedestrian friendly than, observed. today. The underestimation of walk/bike trips was also a function of the lack of integration of the pedestrian mode choice model with the auto/transit mode.choice model-pedestrian trips are subtracted out of total person trips in a "pre-mode-choice" model step even in the enhanced LUTRAQ model. Thus, while pricing and- other TDM measures could divert auto trips to transit or ridesharing, these pricing and TDM measures played no role in the walk or bike mode choice estimation process, which clearly should be sensitive to such things as parking cost and, availability, especially for shorter trips. Despite these shortcomings, the LUTRAQ analysis showed that modest improvement in the quality of the pedestrian environment alone could reduce the Vehicle Miles of Travel in suburban zones by about 10%. Variation in building orientation at the zonal level was also found to account for changes of 10% or more in VMT per household. [9]

The LUTRAQ model was unable to reflect potential improvement of bicycle friendliness, bicycle access to transit, or encouraging bicycle use, due to the lack of available local empirical data. The Portland, Oregon, regional government (Metro) is moving forward to develop GIS-based methods for incorporating additional pedestrian and bicycle related factors into their long range planning analyses.

Sacramento Model. SACOG's model was developed in 1994, based to a significant degree on the Portland, Oregon, model, and incorporates a Pedestrian Environment Factor (PEF). This model was coded and run using the MINUTP software package. It is notable that this model would substantially underestimate non-motorized travel in the region's most bicycle and pedestrian friendly center, Davis, where almost one in three trips is by bicycle, were it not for the inclusion of a special "Davis factor." This highly significant binary variable is applied only to the satellite city of Davis, 20 miles from downtown Sacramento, in order to "correct" for that town's special conditions. One key factor may be the "traffic cell" that has been created in Davis, which forces car traffic to travel circuitously around the central area while allowing direct connections on a very high quality bicycle and pedestrian network on the UC Davis campus, which is the major employment center. Other likely key factors are the extensive separated bikeway network that extends throughout the town, the bicycle-friendly climate of opinion in Davis, the parking pricing and parking management systems, and the zoning restrictions that have minimized freeway/automobile-oriented retail development and preserved the town center's business district. These factors could and should be evaluated in further model refinement, using available Geographic Information System (GIS) and travel survey data."

Experience Outside the U.S. Many European regional models include walk and bicycle travel in a basic way. While many Dutch modelers have developed bicycle network traffic assignments to support bikeway planning, the development of infrastructure sensitive demand models is less well established. Some work in Rotterdam has been reported to this author, but documentation is not readily available.

Many German models, for example all of those developed using the VISEM (TRIPS) software (now also being marketed in the US), explicitly account for walk and bicycle trips in trip estimation, but do not generally deal with bicycle traffic assignment, and deal with walk assignment only in central pedestrian oriented areas. VISEM is an activity chain based traffic demand model that considers the relative frequency of distances by mode of transportation for seven different groups of tripmakers (employees vs. nonemployed, with or without cars; students above vs. below 18 years age; and apprentices), but recommends use of local survey data to calibrate maximum likelihood estimates for these values. Applications of VISEM have not to date included a supply quality variable for pedestrian or bicycle travel, although the model structure could be adapted to this. VISEM's developers suggest that improved bicycle facilities or safety measures for non-motorized travel might be reflected in their model structure through modification of logit model parameters, changes to the access and egress times of the affected zones, and changes in the coding of mode speed or travel time 'for specific origin-destination pairs. Indeed, these same approaches could be used in most conventional U.S. transportation models that explicitly include non-motorized travel modes and their attributes. [11]

Some Swedish regional transportation models, for example some developed by Stephan Algers of Transek AB, include-travel demand models for bicycles as a separate travel mode. As of several years ago, this was a simple model where the share of trips between an origin and destination by bicycle was a function of distance and the share of the trip that could be made on separate bicycle facilities, among other factors, in a nested logit model. Many of these models are coded and run using the EMME/2 software package.

In Shanghai, China, Barton-As&man and INRO consultants collaborated to develop a bicycle network and travel demand model to evaluate transportation plans and projects in the framework of EMME/2 software in the mid and late 1980s. Bicycle travel demand was a function of trip distance, time, and several other factors as part of what this author believes was an otherwise typically structured four step travel demand model with logit mode choice, with separate bicycle, automobile, and transit trip assignments to the network.

III. Modeling Emission Impacts of Factors Influencing Pedestrian and Bicycle Travel

Problems in evaluating the travel behavior effects of factors influencing walking and bicycling are compounded when conventional emission factor models are used to evaluate some of these strategies; In America, most evaluation of mobile source emissions relies on Environmental Protection! 'Agency (EPA's) MOBILE model or EMFACT, the California equivalent. These models depend on speed factor adjustment curves to evaluate how emissions will- change with changes in vehicle operating speed. However, recent research by EPA and the California Air Resources Board indicates that these speed factor adjustment curves are not very robust and frequently lead to improper estimates of emission changes. This is a particular problem in the evaluation of some measures supportive of walking'and bicycling, such as traffic calming and traffic cells, which since the 1970s have become widespread in Europe and are beginning to take greater root in the U.S.

Traffic calming encompasses a wide range of techniques for slowing down motor vehicle traffic to provide an environment more supportive of walking and bicycling and safer for children, the elderly, and others. Traffic calming measures include. narrowing roadways, reducing speed limits, introducing curvilinear elements in formerly straight street to slow traffic, and changing the vertical profile of the street with elements such as raised intersection tables for pedestrian and bicycle path crossings. Although the EPA MOBILE model would indicate that slowing down traffic typically increases emissions, empirical research indicates the opposite in many cases. Research in Germany has shown that the greater the speed of vehicles in built-up areas, the higher is the incidence of acceleration, deceleration and braking, all of which increase air pollution. German research indicates that traffic calming reduces idle times by 15%, gear changing by 12%, brake use by 14%, and gasoline use by 12%. [12] This slower and calmer style of driving reduces emissions, as demonstrated by an evaluation in Buxtehude, Germany. The table below shows the relative change in emissions and fuel use when the speed limit is cut from 50 km/h (30 mph) to 30 km/h (20 mph), for two different driving styles. Even aggressive driving under the slower speed limit produces lower emissions (but higher fuel use) than under the higher speed limit, although calm driving produces greater reductions for most emissions and net fuel savings.[13]

Moreover, by encouraging more use of walking and bicycling and reducing the advantage offered by the automobile for short trips relative to these alternatives, traffic calming usually reduces the number of trips, trip starts, and VMT. Applied on a widespread basis in conjunction with transit improvements and transportation pricing changes, traffic calming may contribute as well to a reduction in household automobile ownership levels, further reducing emissions and travel demand. Thus, even in circumstances where individual vehicle emissions per mile traveled increase due to more aggressive acceleration, braking, and use of second gear, traffic calming will likely lead to overall emission reductions due to its influence on travel demand.

A recent FHWA report discusses the German experience with traffic calming in six cities and towns in the early 1980s:

> "The initial reports showed that with a reduction of speed from 37 km/h (23 mph) to 20 km/h (12 mph), traffic volume remained constant, but there was a 60% decrease in injuries, and a 43% to 53% reduction in fatalities. Air pollution decreased between 10% and 50%. The German Auto Club, skeptical of the official results, did their own research which showed broad acceptance after initial opposition by the, motorists. Interviews of residents and motorists in the traffic calmed areas showed that the percentage of motorists who considered a 30 km/h (18 mph) speed limit acceptable grew from 27% before implementation to 67% after implementation, while the percentage of receptive residents grew from 30% to 75%."[14]

Change in Vehicle Emissions and Fuel Use with Speed Change from 50 km/h to 30 km/h

Emission Type	Driving Style	
	2nd Gear Aggressive	3rd Gear Calm
CO	-17%	-13%
HC	-10%	-22%
NOx	-32%	-48%
Fuel Use	+7%	-7%

This experience of initial skepticism of traffic calming, followed by its widespread popularity after implementation, has been experienced in hundreds of communities across Europe, Japan, and Australia, along with the few U.S. communities which have adopted such strategies, such as Palo Alto, California, and Seattle, Washington. Unfortunately, most U.S. transportation models and evaluation methods are ill-suited to reflect these empirical effects. Work is needed by EPA and others to evaluate traffic calming effects on emissions and travel behavior in varied American community settings.

Many places in Europe and Japan-from cities like Göteborg, Sweden, and Hannover, Germany to Osaka, Japan, from suburban new towns such as Houten, Netherlands, to established automobile-oriented suburban centers like Davis, California-have successfully implemented traffic cell systems. These typically consist of a set of radial pedestrian, bicycle, and transit-only streets focused on a central area. While pedestrians, bicyclists, and public transportation can freely cross these streets, automobile traffic cannot, but must instead use a ring road around the center. Traffic cell systems are very effective at eliminating through traffic in central areas and shifting short automobile trips in the central' area to walking, bicycling, and public transportation, significantly reducing cold start and evaporative emissions. By reducing central area traffic and increasing street space dedicated to walking, bicycling, and public transportation, these alternatives become more' attractive and parking requirements in the central area diminish. Success in reducing environmental impacts is dependent on curbing automobile-oriented peripheral development.

Göteborg, Sweden,. introduced traffic cells in mid-1970s together with priority for public transport at signals, new suburb-to-downtown express bus service, and central area.parking controls. Traffic accidents were reduced 36%, noise was cut from 74 to 67 db. in the main shopping street, peak CO levels dropped 9%, 17% fewer cars entered the center city, weekday transit trips to the center were up 6%, traffic-on the inner ring road was up 25%, and the costs of running public transport went down 2%. Nagoya, Japan,. introduced traffic cells in residential areas in the mid 1970s, together with computer managed signal system; bus lanes, bus priority at signals, staggered work hours, and parking regulation. This resulted in a 17% increase in traffic speeds on main roads covered by the signal system, a 3% increase in bus ridership. Traffic deaths in traffic cell areas fell 58%, 15% fewer cars entered the central area in the morning peak, and auto-related air pollution decreased by 16%.[15]

The Downtown Crossing pedestrian zone,. in Boston, Massachusetts, is a-limited traffic 'cell serving a core area with 125,000 employees-~ Eleven blocks of the central business district were closed to traffic in 1978, while steps. were taken to improve transit service and parking management. In the first year, there was a 5% increase in visitors to the area, a 19% increase in weekday shop purchases, a 30% increase in weeknight purchases, an 1 1% increase in Saturday purchases, a 2 1% increase in walking.trips to the area, a 6% increase in transit trips to the area, a 38% decrease in auto trips to the area, and no increase in traffic congestion on adjacent streets, thanks to elimination of on-street parking and stricter parking enforcement on nearby traffic streets.

Clearly, more research is needed on how to incorporate strategies like traffic cells and traffic calming into regional. transportation models, DOT and EPA, along with local, regional, and state agencies, should cooperate in advancing our knowledge in this area and integrating into mainstream planning and program evaluation practices.

IV. Measuring Bicycle Friendliness

In the past several years, some analysts have worked to develop- indicators of bicycle Level of Service (LOS), bicycle friendliness, bicycle stress level, bicycle suitability of streets, and the like: Some of these have been used to help create consumer-oriented bicycle maps, while others" have been developed for modeling and facility need identification purposes. Bruce Epperson, a Senior Transportation Planner at the Miami Urbanized Area MPO, recently summarized much of. this research.[16] -However, little of this work has been integrated with regional travel demand model, development.

Alex Sorton, at Northwestern University Traffic Institute;, and Tom Walsh, from Madison, Wisconsin, DOT, have developed the concept of "stress levels" to estimate the relative compatibility of roadways and different types of bicyclists. Their stress level index, ranging from 1 to 5, is based on curb-lane traffic volume, motor-vehicle speed, and curb-lane width, using peak period traffic conditions.[17] This stress level model is already being used in several cities, including Arlington, Texas, and Bloomington, Indiana. FHWA has funded a two-year research project to validate this method, using videotaping and cyclist ratings. In a project for the Regional Transit Authority in Chicago, a consultant team headed by Wilbur Smith Associates, that includes Allan Greenberg of the League of American Bicyclists and others, is exploring use of videotape and a combination of revealed and stated preference surveys to evaluate bicycle friendliness to help estimate the potential for bike-and-ride access to rail stations and other transit as part of a nested logit model. A key challenge will be how to relate these measures to discrete travel behavior choice in the broader context of all travel choices and to develop low-cost methods for estimating bicycle stress and related factors across an entire region. Unfortunately, the study does not appear to include measures of the potential response to guarded bicycle parking at stations, although this has superior characteristics to both bicycle racks and lockers and is the most commonly used type of rail station bicycle parking found in the European and Japanese communities where bicycles are the predominant access mode to express transit,

Measures of bicycle and pedestrian "friendliness" are essentially measures of the, utility offered by these modes in different contexts. It is difficult to come up with simple but consistent measures that can apply to the wide range of travelers who under varying conditions might choose or not to use a bicycle or to increase their propensity to walk. Market choice modeling techniques provide valuable tools to measure the significance of various factors in explaining travel behavior, including traveler response to changes in the pedestrian and bicycle environment and the larger transportation and land use system.

A *Data Collection Case Study of Portland Oregon,* is to be prepared with support from the federal Travel Model Improvement Program to illustrate the application of leading edge, state-of-the-practice data collection to develop transportation models, including non-motorized modes.[18] However, further research focused more specifically on how to measure non-motorized transportation utility factors and their variance among different types of travelers will be needed to advance cost-effective data collection and model development in a greater number of regions.

X. Recommended Steps Forward

There is a critical need for improved analysis tools to evaluate the effects of bicycle and pedestrian projects and programs on travel demand and how these interact with broader changes in transportation system performance and costs, land use, and urban design. There is a paradigm shift underway in transportation modeling, with a shift away from aggregate analysis of motor vehicle travel towards discrete choice models based -on microsimulation of activities and time use. The new paradigm seeks to consider the entire spectrum of travel, modes,,time-of-day of travel effects, trip chaining, life-cycle effects, urban design factors, pricing sensitivity; and the potential for communications and information systems to affect travel choices.? The Federal Travel Model Improvement Program (TMIP), coordinated by the Texas Transportation Institute with DOT and EPA funding, has since 1993 been supporting research on new modeling techniques and training for transportation modelers. TMIP has recognized the need to integrate non-motorized travel into model development and research and has documented, some of the U.S. experience with'this. However, it has not undertaken any projects designed to advance the state&-the-art in this area.

TMIP's advanced model development track is focused on the TRANSIMS simulation model development at Los Alamos National Lab, using supercomputers to do advanced microsimulation of activities, travel behavior, and emissions. It is important that this work fulfill its early promise to incorporate explicit representations of walking and bicycling and the environmental factors shaping use of these modes. There has not been evidence of such progress to date, but the project is still only two years into its five year work program and a practical applied modeling system is still some time off. DOT should ensure that this element is integrated into TRANSIMS and shows progress in the coming year. 'The involvement of an expert in non-motorized transportation modeling- as a subconsultant to this project should be sought to ensure that a sound approach is taken in this important research and development project. TRANSIMS elements should be tested in the context of a community where substantially higher than typical use of non-motorized modes is in current evidence to give a suitable empirical basis for development of these model elements. Current TRANSIMS testing in the Dallas&Fort Worth region is not satisfactory in meeting this requirement. Progress in TRANSIMS to date appears to be imbalanced, focusing early applications on traffic simulation while activity analysis'and system elements for 'multi-modal evaluation appear to be lagging. This is of growing concern to the environmental community and should. be addressed by the TMIP-program managers and Los Alamos.

An immediate priority should thus be for the demonstration of 'advanced state-of-the-art travel models with substantially greater inclusion of pedestrian/bicycle travel factors, working in one or more- regions where data and agency interest can support rapid and efficient progress. While several planning agencies and researchers are interested in developing improved models sensitive to pedestrian and bicycle' friendliness factors, progress has been limited by a lack of funding for pilot projects with such a specific objective.

Unfortunately, at many other planning agencies, transportationmodelers continue to regard the inclusion of pedestrian and bicycle travel and factors in regional models as a longer term objective to satisfy pressures from stakeholder groups, not as something vital to address in current model refinement work. It is important that federal research funding not focussolely on how to advance the state-of-the-art, but also on how to quicklyimprove the unacceptable current transportation modeling practices that commonly ignore or unfairly disparage the potential for pedestrian and bicycle programs to make cost-effective contributions to improved air quality, traffic congestion relief, and traffic safety. Thus, a second, related area for research funding should also be immediately pursued. This trackshould develop and document methods for near-term improvement and disseminate them to modeling practitioners.

As the advanced modeling track progresses, it will provide empirical support for further development of the quick-fix modeling track and integration of these two approaches. It would be desirable to support coordinated advanced travel modeldevelopment work in two or more regions concurrently to help assure progress in this area of travel. model improvement and to provide the basis for' later estimating much refined multi-region models using logit coefficient scaling techniques; Longer term diffusion of these pedestrian/bicycle sensitive models will be accelerated if transferable multi-region modeling techniques are developed for both sketch analysis and more detailed evaluation systems. Once a new generation of -advanced,. travel models has been developed with broader sensitivity to factors that can be measured using GIS techniques and data, it should be possible to calibrate on these data sets refined sketch models that build on the quick-response methods. and surrogate data sets used in the quick-fix. track. This offers promise for improving the transferability of models between regions.

On the basis of this review, two specific and inter-related areas of work are recommended as immediate high priorities for research, development, and demonstration funding, one to advance the state-of-the-art in several regions where adequate data and model development expertise is readily available and the other to provide more typical regional planning agencies with improved, policy-sensitive quick-response analysis methods that can be readily- adopted anywhere.

A. Advanced Regional Models Integrating Non-Motorized Modes and Factors

This work would support data development and analysis of factors related to pedestrian and bicycle friendliness and the use of these factors in estimation of new regional-travel models. This work should be undertaken in one or more regions with a recent or about to be collected household travel/activity survey. The survey should include a significant sample-of walking and bicycle trips. The region should have an established. GIS that could support estimation, of measures of pedestrian and bicycle friendliness, and should display a variety of environments for walking and bicycling. Model development should examine sensitivity of travel demand, both motorized and non-motorized, to changesin street allocation and design, traffic conditions, land use density and mix, transportation pricing, demographics, topography, and other factors. Street address/intersection GIS-based georeferencing of householdand employer-based travel survey records, along with the use of real estate parcel databases and TIGER-based inventories of bus stops and pedestrian/bicycle systems can enable relatively inexpensive examination. of the influence of pedestrian and bicycle environmental quality and urban design on travel behavior, and, interaction with other factors.[20]

There are several transportation planning agencies that have such datasets whichcould be linked to estimate such pedestrian/bicycle sensitive travel demand models and where there is strong potential interest in developing such tools, particularly if funding is available for additional consultant and staff time support. These include:

- **Sacramento, California.** Dr. Robert Johnston, at the University of California/Davis, has worked extensively with the new SACOG model and is developing a GIS-based land use/transportation model (TRANUS) for the Sacramento region. Gordon Gery, SACOG's chief modeler, is also interested in exploring ways to improve the agency's model to non-motorized travel factors,, There is a recent Sacramento regional travel survey including 4000 households,. which has been cleaned up by several people, including Greig Harvey, who examined every individual record for surveyor and respondent errors. A smaller 2400 household sample drawn from this. survey,, which includes only households reporting income and ages, is used for auto ownership and mode choice model development. A 1994 on-board transit survey- supplements, this. Work in this region would likely focus on improving and advaneing'the classical "four-step" transportation modeling process.

- **Portland, Oregon.** Keith Lawton, Deputy Director of Planning at Portland Metro, has recently managed the collection of state-of-the-art household activity surveys throughout the Portland region and Willamette Valley; including Eugene, Oregon, which exhibits high levels of bicycling. He has collected data on 440 bicycle trips out of 2200 households in the Portland region, and observed a 9% walk mode share for total travel (with variance from 5% to 29% of trips between different areas of the region). This, 1994 survey data are now undergoing detailed cleaning and analysis for model development work in 1995-96. Metro has already begun to evaluate indicator variables using a GIS to replace the cruder Pedestrian Environment Factor. Metro's next generation models will likely represent a transitional approach that incorporates many of the elements of activity analysis and microsimulation, while retaining some of the framework of more classical methods.

- **Boston, Massachusetts.** John Bowman, a Ph.D. candidate at Massachusetts Institute of Technology and a student of Moshe Ben-Akiva, who is a leader- in the field of discrete choice modeling theory and applications, in early 1995 developed a proposal for advanced modeling methods sensitive to pedestrian and bicycle factors. It has not yet secured any funding but merits support. This work could bereadily conducted in the Boston region, where there is growing local government support for traffic calming and other strategies supportive of non-motorized transportation. Moshe Ben-Akiva and John Bowman presented a paper at the 1995 Transportation Research Board (TRB) Annual Meeting on his activity based modeling research and modeldevelopment, which has been widely praised as innovative and practical?' This pedestrian/bicycle work would build on that new framework, which is at the cutting edge of applied regional modeling.

- **Denver, Colorado.** The City of Boulder, Colorado,and the Denver Regional Council of Governments (DRCOG) is another possible venue for such research, with a recent household travel survey for Boulder County that covers a portion of the region and exhibits wide variation in bicycle and pedestrian travel and conditions, with very high non-motorized travel rates in central Boulder. DRCOG has a GIS but has not evaluated pedestrian and bicycle friendliness factors. DRCOG plans a new regional household travel survey in 1996, since one has not been conducted for many years. Following this survey, DRCOG plans to develop a new generation transportation modeling system. Work in this region would likely be firmly rooted in the classical four-step modeling approach, but might bring in some of the concepts of activity analysis after a new regional travel survey has been undertaken and processed in 1996-97.

B. Quick-Response Models Sensitive to Pedestrian and Bicycle Travel Factors

Most U.S. communities lack the modeling tools and data for development of state-of-the-art transportation models sensitive to non-motorized travel factors. While they could and arguably should-invest in expeditious development of such tools, the reality is that they will likely take several years to upgrade their current models to meet current best practices, which still fall quite short of what is needed for evaluation of pedestrian and bicycle programs and strategies. Thus, it is important for DOT/EPA to also support near-term quick-fix strategies for adjusting typical regional four-step computer transportation models to correct for their lack of sensitivity to pedestrian and bicycle travel factors.

Empirical measurement and analysis drawn from regions in North America and elsewhere exhibiting widely varying levels of non-motorized travel can reveal much about the range of response to different strategies in varying contexts. This quick-response approach would seek to adapt and synthesize available model coefficients from regions with models sensitive to pedestrian/bicycle travel factors, using logit model coefficient scaling.[22] This work could be complemented with other transferable parameters based on before/after evaluations and cross-sectional research studies. To support this approach, a survey should be undertaken of U.S., European, Canadian, Australian, and Japanese transportation models and research incorporating measures related to pedestrian/bicycle travel, building on limited research done to date. [23] This will provide one basis for quick-fix model development.

It would be most valuable for this work to consider also the interactions of pedestrian/bicycle travel factors with related and potentially supportive strategies, including:

- improvements to the quality of the pedestrian and bicycle environment, traffic calming, development of traffic cell systems, comprehensive bicycle network development;
- improved bicycle and pedestrian access to and from public transportation;
- market-based pricing strategies, including electronic road pricing, pay-by-the-mile automobile insurance and VMT-based registration fees, parking management; and commuter choice programs;
- growth management and land use policies, including encouragement of transit oriented development, accessory apartments for infill, and greater pedestrian proximity to convenience retail services.

Consideration of these interactions can be accomplished only by integrating walking and bicycling into the full regional model structure. However, experience from other regions and sensitivity tests using models from other regions can provide the basis for estimating likely changes from baseline conditions for specific areas.

Because local data on pedestrian/bicycle travel and conditions are not widely available (indeed, regional travel surveys commonly have ignored or under sampled non-motorized travel), it is important to also explore how universally available data can be used to devise quick response methods. "Quick-fix" modeling techniques should be grounded in baseline estimates of current conditions, preferably at the traffic zone or census tract level. Surrogate factors could be correlated with pedestrian/bicycle travel to establish estimated baseline conditions for pivot point modeling, where local data are limited. For. example, the data for housing unit construction and residential density can be drawn directly from Census Public Use Microdata

Samples (PUMS). Census TIGER file data can provide measures of networkconnectivityand density. The National Personal Transportation Survey (NPTS) can provide micro sample travel survey data for non-work travel which can be linked to PUMS data using statistical inference for quick development of microsimulation modeling tools where regional travel survey data are lacking. Census Journey-to- Work data can provide additional data on work travel mode shares and other aggregate travel characteristics by small areas, with larger sample sizes.

Integrating these universally available data elements can provide a framework for development of potentially transferable regional microsimulation models sensitive to transportation pricing and pedestrian/bicycle friendliness, building on earlier work by Greig Harvey in California, Chicago, and elsewhere.[24] Indeed, Michael Replogle and Greig Harvey are in the earliest stages of a collaboration to explore such links in the New, York metropolitan region, in cooperation with the New York Metropolitan Transportation Commission (NYMTC), the region's Metropolitan Planning Organization. An application for limited funding for this work is pending; additional support would be most valuable to support more extensive examination of pedestrian/bicycle travel factors in the NY region. NYMTC itself continues to work with an early 1970s vintage highway model that is generally insensitive to transit, walking, a&bicycling, but has extensive work underway to develop a large regional household travel survey in fall 1995 or spring 1996 to support development of a new multi-modal -regional transportation model. Michael Replogle is a member of NYMTC's transportation modeling advisory committee and Greig Harvey is a member of the consultant team for the larger NYMTC modeling effort being carried out by Parsons Brinckerhoff Quade and Douglas.

This effort might seek to develop and document in a relatively short time a new and potentially transferable regional model sensitive to the effects of changes in pedestrian/bicycle factors and other transportation system elements on motor vehicle use.. This could be coded as a spreadsheet logit model for pivot point analysis, accompanied by case study documentation, or as a set of macros that, could work with commercially, available transportation modeling software packages. These quick-fix techniques might then be transferred to several other regions where they might find the greatest utility, and this experience might be documented for further dissemination. The New York metro area would. be a good venue in which to develop and demonstrate these tools, -given current opportunities, needs, and dataconstraints.

It may also be useful to consider other regions that present potentially promising opportunities foradvanced or quick-fix model development or to demonstrate how techniques can be successfully transferred between regions. Cooperative agreements and small pilot grants to local governments, MPOs, state DOTs, universities and non-governmental organizations, as well as targeted contract technical assistance could be a catalyst for progress in these regions., Such-opportunities might include Chicago, where work could build on the effort now being done for the RTA; northern New Jersey, where a Route 1 Transportation Collaborative project is getting underway and might focus on enhanced evaluation of pedestrian/bicycle strategies; one or more cities in Florida, where the State DOT has been working for years to improve pedestrian and bicycle conditions and also supports a statewide travel model; Montgomery County, Maryland, where extensive survey and GIS data sets have been developed but not fully exploited; or other regions.

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TRAVEL IMPACTS OF URBAN FORM: IMPLICATIONS FROM AN ANALYSIS OF TWO SEATTLE AREA TRAVEL DIARIES

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INTRODUCTION

Purpose of Research

Over the past 30 years, a notable change in land use has been the growth of residentially oriented suburban neighborhoods located some distance from employment and service *centers. Linked with this growth are increasing levels of traffic congestion, air pollution, and general disenchantment with suburban life (Downs 1992; Langdon 1994). These negative impacts have focused on the' potential transportation benefits of traditional oriented neighborhoods characterized by more diverse land use development patterns (Bookout 1992a, 1992b). Developers: and planners have suggested that mixing land uses can reduce automobile dependency by making more goods and services available within walking and short driving distances. The new interest in'mixed land use represents an about-face with regard to the basic assumptions that have shaped urban development patterns over the past 20 or 30 years.

While interest in mixed-use development is on the rise, only a handful of studies have explored the transportation "implications of this type of 'development empirically. Existing studies typically contain only jgeneral information on the demographic characteristics and travel patterns of inhabitants of mixed-use areas. This research' seeks to address at least part of this 'gap in the literature. The researchers 'used 'a two-day travel diary and demographic survey of 900 households in three greater Seattle area neighborhoods characterized by two 'or more distinct land uses. This detailed data set was then compared'with similar household travel data collected by the Puget Sound Regional Council (PSRC). Both data sets used similar survey forms and were collected and coded by the same contractor. The data were compared to see whether the travel behavior of residents of mixed-use neighborhoods differed significantly from the travel behavior of residents in neighborhoods with more homogenous land use patterns.

One goal of the research described herein was to explore whether people in neighborhoods that provide goods and services travel less than people in other more homogenous neighborhoods. This study, unlike previous research on mixed-use, approached this question using detailed, empirical travel data collected *specifically* to explore the travel characteristics of mixed-use neighborhood residents. The travel data were designed to be compatible with similarly detailed regional level travel survey data from the PSRC. This effort resulted in the ability to compare and contrast the travel patterns of mixed-use neighborhoods to other areas.

In addition to the above comparisons, a second goal of this research was to explore the nature of weekend travel in the mixed-use neighborhoods through a variety of measures.

Analysis

This research had two major elements, the first of which was a county comparison of **weekday travel.** Insofar as the mixed-use travel survey was designed to be compatible with the PSRC county level survey (PSRC's survey was for four counties, this research only needed King County), it was possible to explore the differences in travel characteristics between non-mixed-use areas and mixed-use areas by comparing the PSRC's county level data with the neighborhood data.

The second element of this research was ,a descriptive examination of **weekend travel.** The mixed-use data used for the weekday research also collected travel information for weekends. Because weekend travel is little studied, the mixed-use survey results provided a welcome opportunity to consider this travel behavior separately.

Both elements of this research considered the following categories of analysis: travel times and distances, demographics, multi-purpose trips, and intra-neighborhood analysis.

Travel Times and Distances. The use of transportation modeling output, Geographic Information Systems (GIS) software (TransCAD), and a U.S. Census-derived computer file of the county street network allowed for calculation of a number of important spatially-oriented travel statistics. Most relevant was the ability to estimate respondents' trip mileage in the mixed-use neighborhoods, both individually and as households, from original survey data by estimating travel routes on the street network. The travel distance procedures also provided the ability to accurately calculate short trip distances. Travel times were reported directly in both data sets and provide valuable information.

Demographics. Household and individual demographic characteristics were compiled to- identify possible correlation with observed travel patterns in each of the study neighborhoods.

Multi-Purpose Trips. Many people schedule their activities by combining several trips into a single, sustained journey or chain. Analyzing the number, length, and type of chains, as well as the characteristics of the trip, maker, sheds light on how travel is organized for efficiency, especially around work trips.

Intra-Neighborhood Analysis. Each of the three mixed-use neighborhoods encompassed concentrations of retail and other service establishments. This research examined the travel patterns of households at various distances such concentrations, and explored the extent to which proximity to commercial outlets and services affected the mode choice other than the auto-and in particular, whether walk trips replaced vehicle trips for short-distance travel.

Analysis Limitations

This analysis is limited in several respects. Since the research is based on survey data, it is possible that some variation in travel behavior is attributable to self-selection by certain types of individuals in different neighborhoods. It is difficult to measure this type of bias.

The research also compares the PSRC panel survey data with the mixed-use neighborhood data. While the research designs for the projects were similar, the two surveys were conducted two years apart, increasing the possibility of some incompatibility between the data sets. Additional incompatibility may result because the PSRC data were collected September through December, while the mixed-use data were collected only in November and December. As a result, the mixed-use data could be biased toward shopping trips because of the increase of retail activity during the Christmas season. The two data collection efforts also used slightly different sampling procedures, and the mixed-use survey form was more comprehensive, resulting in other possible limitations when comparing across data sets.

The PSRC panel survey instructions requested that the participants report all trips five minutes or longer. Since pedestrian, bicycle and short vehicle trips are important in studying mixed-use neighborhoods, the mixed-use data instruction requested that all trips be included. In spite of this difference in instruction, both "data sets include. similar percentages of trips less than five minutes long. The mixed-use data included 7.0 percent of the trips less than five minutes, while the PSRC data set had 6.5 percent of all trips. However, for the most accuracy, when possible, any comparison between the two data sets removed all trips under five minutes in length.

The PSRC panel data and the mixed-use data both constituted two-day travel diaries. Naturally, travel on one of the two days is not independent of the other; nor, for that that matter, are trips within a single day independent for a given person or between people. While this may cause problems for some types of analysis and for developing travel models, this study is merely comparing similar households across various types of geographic areas.

Report **Structure**

The remainder of this paper is divided into six sections.

Literature Review, The research literature concerning empirically oriented analyses of neighborhoods with mixed-use characteristics is reviewed, identifying the scarcity of quantitative analyses of neighborhood travel behavior, particularly as they relate to land use. The few empirical studies on weekend travel are also covered.

The Data Sets. This section discusses the two data sets used for the study. First, a brief review of the data collection methodology is given. Since the subsequent analysis of the data set requires specific knowledge of trip locations (origin and destination), the process by which those locations were derived from the survey responses and coded (i.e., the geocoding process) is discussed. The PSRC data set used for regional comparisons is also discussed. This discussion concludes with a comparison of the mixed-use and PSRC data sets; several key differences between the data sets are highlighted.

Research Methods. This chapter reviews the techniques and issues associated with processing and preparing the data for computer analysis.

Data Analysis — Weekdays. The mixed-use data and the panel survey data are analyzed statistically and spatially. The major findings from the comparison of these data sets are then discussed and compared with those of other studies.

Data Analysis — Weekends Travel in the mixed use neighborhoods for weekends is analyzed and numerous descriptive statistic regarding weekend travel are presented. General travel characteristics, day and time variations, as well! as a separate look at walking trips provide insight into the weekend travel patterns of the mixed land use neighborhood residents.

Summary and Future Research. The results of this research are summarized and the conclusions are presented.

LITERATURE REVIEW: TRAVEL IN MIXED-USE NEIGHBORHOODS WEEKDAYS AND WEEKENDS

General Travel

The **Nationwide Personal Transportation Survey (NPTS)** is a randomly sampled telephone survey collected every few years designed to provide a comprehensive look at personal travel in the United States. The 1990 survey and the three earlier surveys provide data (although no origin and destination data) useful in examining the, relationship among demographic, **land use, and transportation** changes, The following threesummaries are from studies that utilize these data. ,

According to **Comsis** (1994) vehicle miles of travel **(VMT)** increased nationwide by 37 percent between 1983 and 1990, although the population only **increased** by 4 percent. The report indicated that higher. residential and employment **densities** can **promote** less reliance on private vehicle trip making: "Persons residing inside' the central 'cities of urbanized areas make more shorter trips than persons living outside central cities."

Pisarski (1992) used the weekday data from the Nationwide Personal **Transportation** Survey **(NPTS)** and found that "the geographic distribution of population is far more crucial than population growth in creating **dramatic changes in** travel, in individual, locations." He indicated that **one** of the most significant factors in trip growth is the population shift to large **metropolitan areas, and subsequently** to these areas' suburbs.

Gordon and Richardson (1994) published another NPTS-based study. They sought to explain changes in work trip length and determined: that **although** trip lengths : **have** increased, so have travel speeds. Their findings support the view that suburbanization allows people to live farther **from** activity centers **at** a modest. marginalcost in terms of extra time traveled, due to higher speeds: In contrast to **almost** every other researcher, they conclude that "urbansprawl is a transportationsolution, not a problem.'"

Trip Characteristics and Travel Patterns of Suburban Residents by **Prevedouros and Schofer** (1991) analyzed. weekday travel, behavior based on a 1.989. mail-back **survey** of individuals residing in selected Chicago suburbs. One of four factors analyzed were two classes of suburbs: **inner-ring,** high density, stable suburbs; and **outer-ring,** low-density, growing suburbs. Key general findings indicated that residence location in outer&ring suburbs implies longer trips and more frequent local trips. Although the average travel speed by automobile is higher for residents of growing suburbs; they **still stay** in traffic 25 percent, longer and have a **40** percent **longer** total daily distance, compared with stable-suburb residents.

In a more general study, the **Puget Sound Council of Governments (PSCOG)** published a **report** in **1990** on household -travel surveys from the counties in 'the Seattle metropolitan area. -One- to three-day, traveldiaries **were collected** from **4,500** households. between, 1985 and 1988. The survey's purpose was to update earlier, survey' research for use in travel demand forecasting: and planning. Results indicated that **while** householdsize is decreasing,,-the smaller households have more vehicles; The surveys confirmed that trip making per person and per household **have** increased substantially **(Table 1)** and: that nearly **90** percent of all trips are made by private vehicle. Average vehicle occupancy in the region declined from 1.25 persons per vehicle in 1961 to 1.1 in 1987.

Table 1. Person Trips in Puget Sound Region

Year	Average Number of Person Trips per Person in Puget Sound Region
1971	2.6
1987	4.3

source: PSCOG 1990

Summarv of General Travel

Empirically based travel studies generally indicate that travel is increasing, and that residents outside the central city travel longer and farther; although at higher speeds, than inner ring residents **(Table 2).**

Travel in Mixed-Use Neighborhoods

After studying southern California, **Giuliano (** 1995) contended that the connection between land use and transportation is negligible because urban areas in the U.S. are already so accessible, because settlement patterns are well-established, and because privacy is so important to, most people. As such, transportation plays an ever-decreasing role in the locational decisions of households and businesses. Her essay implies that the land-use transportation connection is too weak to provide of public policy direction.

Cevero and Landis (1995) rebutted Giuliano's article. Although they agreed that **the** connection is much weaker today than a century ago, they argued that the relationship remains important. In support of this view, they cited studies showing how land prices have gone up around new transit stations and commute trips that tend to be shorter for those living in areas with balanced housing and jobs. They conclude that land use can be an important contributor to transportation trends and vice versa. The authors expressed belief that, in the land use-transportation connection, considerable elasticity remains.

Another study to examine the land use connection to transportation was **Frank and Pivo (1994),** the first in a series of projects seeking **to identify** which land-use patterns reduce auto use. The authors studied 1989 travel in the greater Seattle/Tacoma region and found that commute distances and times tended to be shorter for those inhabitants of balanced areas. More specifically, the average length of work trips ending in a balanced census **tract** was 29 percent **shorter than** work trips that end in unbalanced **areas (Table 3).**

Table 2. **Summary of General Travel Studies**

Author	Key Findings
Comsis	Travel increasing due to increased trip frequency and length higher densities and living inside central cities promote shorter trips
Pisarski	Geographic distribution of population 1s more important than population growth in travel patterns changes.
Gordon et al.	General travel trends indicate longer trip lengths but also higher travel speeds
Prevedouros et al.	Outer ring growing suburb residents make 40 percent longer trips (but have higher travel speeds), spend 25 percent more time in the car, and make more frequent local trips than residents from inner ring stable suburbs.
PSCOG	Household size and vehicle occupancy decreasing, while there are more vehicles per households, and more trips per person.

Table 3. 'Work Trin **Length in Puget Sound Area**

Balance of Census Tract where Work Trip Ends (jobs to household ratios)	Distance of Work Trip (miles)
Balanced area (ratio = 0.8 — 1.2)	6.9
Unbalanced area (ratio < 0.8 or > 1.2)	9.6

source: Frank and Pivo 1994

In a later study, Pivo et al. (1995) examined the market for less auto dependent land use by studying 19'70 - 1990 data on the population. density, housing density, employment density, jobs-housing, balance, and; retail-housing balance of both metropolitan cities and unincorporated areas in Washington state. Through examination and comparison of statistical distributions, relationships between land use variables were found, and associations between both density and 'balance and less auto. use were confirmed. The report recommended promoting greater density and balance to communities whose land-use 'patterns are capable of supporting greater transit use and iess out-commuting.

In 1992, a series of articles by **Bookout** in ***Urban Land*** explored .neotraditional development. In the first article (Bookout 1992a) the author argued that the 45 percent of the population that moved to the suburbs after World War II never really realized the American dream due to traffic snarls, inadequate social services;' etc. One of the major flaws with the suburban vision is excessive travel needs brought on by low-density development. The author recommended neotraditional communities, with (among other things) more through streets instead of cul-de-sacs, to give drivers alternate routes between points, which may result in shorter and less congested travel.

A second article, "Cars, Pedestrians, and Transit" (**Bookout 1992b**), asked whether people must continue to drive between each and every one of the places they visit regularly. The author suggested that with the building of more neotraditional communities, the answer should be "no." He advocated three items to reduce either the number of vehicle trips or trip distances:

1. A return to the grid pattern for streets, or at least an effort to provide more direct connections between any two points within a community.
2. Communities that are pedestrian and bicycle friendly.
3. Increased transit viability.

Bookout cited Kulash's study (1990) to substantiate his recommendations. **Kulash's** study used simulation modeling to compare the traffic patterns of developments with densely gridded streets (called "traditional neighborhoods" but referred to as "neotraditional" by most authors and in the remainder of the paper) to communities with partially connected streets and cul-de-sacs (called "conventional suburban developments"). The author analyzed the travel performance of the theoretical developments'and found that a traditional neighborhood design could produce fewer total vehicles miles traveled than a comparable conventional suburb (although much higher travel on local streets) (**Table** 4). Traditional neighborhoods did have lower travel speeds, but trips were **also shorter.** He concluded that traditional street networks function more efficiently than do conventional networks. However, this study did not measure trips beginning or ending outside the community. 'Nor did he indicate whether a traditional development would actually generate fewer trips 'than a conventional development.

McNally and Ryan (1993) used modeling to explore potential **transportation benefits** of neotraditional neighborhood 'design. They compared the traffic performance .of a conventional suburb (with a hierarchical street network) to that of a neotraditional community (with highly connected gridded streets). All aspects of the theoretical neighborhood including land use, were held constant except for the actual configuration of the networks. The models indicated 10 percent' fewer vehicle-kilometers, traveled in the n&traditional network' for the same level of trip generation. 'Total vehicle-hours traveled in the neotraditional network were reduced by 27 percent and the average trip lengths were 15

Table 4. Vehicle Miles of Travel in Theoretical Communities

Vehicle Miles of Travel (internal travel only)	Difference Between Traditional Development (TND) and Conventional Suburb (CSD)
Arterial Streets	TND is 25% of CSD
Collector Streets	TND is 15 % of CSD
Local Streets	TND is 400% of CSD
Total Vehicle Miles Traveled	TND is 57% of CSD

source: Kulash 1990

percent shorter than in the conventional network. The authors concluded that with 'the same level of activity, neotraditional networks operate more effectively,. experience less congestion, and require less travel than conventional. networks. They also indicated the drivers in, neotraditional networks may choose more direct routes.

Friedman, Gordon, and Peers (1992) compared, 1980 travel data from traditional communities 'to suburban tract' developments in the San Francisco bay area in order' to investigate any differences in trip generation and 'mode choice: The older communities developed prior to World War II had gridd'ed 'street networks 'and were characterized by a mixture of residential and non-residential uses. In contrast, the suburban developments tended to contain many cul-de-sacs and segregated land use,. and a hierarchical roadway. In order to control for income, differences, the wealthiest and poorest households in each neighborhood.. were eliminated from the study. The results, which provide 'a basis .for measurement of the potential impacts of different land use patterns, showed that suburban areas generated 23 percent more trips, had higher drive alone rates (68 percent in suburban neighborhoods versus 49 percent in traditional communities), and had half the transit share of traditional' communities. The authors concluded that traditional neighborhoods have characteristics that result in fewer automobile trips than do newer suburban developments.

Although, the Friedman et al. study is widely cited as "proof" of. mixed-use neighborhood transport&on advantages, others counter that it, is impossible to separate out the. relative importance of, the many differences between suburban and traditional communities. **Crane (1996),** for example,, praised neotraditional town planning for its thoughtful and functional design, but he questioned its actual transportation benefits. He pointed out that. transportation problems, may, in fact, worsen—while it is likely that many elements of the new designs discourage driving for some kinds of trips, the aggregate effect is uncertain. Here's why:.

The rectilinear grid street pattern is the easiest transportation feature to implement in neotraditional town planning and is widely encourage by many observers (e.g.,' I&lash,

McNally, and Ryan). However, these authors assumed that trip frequencies are fixed; they never analyzed the potential change in demand for trips due to the new street pattern. Crane agreed that the grid pattern creates more access and thus shorter average' trips than a cul-de-sac pattern. However, he countered that the increased access reduces the cost of travel, thus encouraging people to take *more* trips. He concluded that a change in' street configuration may or may not reduce auto travel, that the transportation benefits of neotraditional designs have been oversold, and that each development must be evaluated on a case-by-case basis to predict the net use.

Another study skeptical of the supposed 'transportation advantages of mixed land use is **Kitamura, Mdkhtarian and Laidet** (1994). This study used travel diaries. and attitude surveys to explore travel behavior in five diverse neighborhoods in the San Francisco area. Initially they showed that neighborhood characteristics were significantly related to travel behavior. Measures associated with lower rates of travel included higher residential density and more mixed land use. The next step of the study attempted to demonstrate that attitude, not land use, was the primary determinant of travel 'behavior. By showing that attitudes were more strongly correlated to travel behavior than neighborhood characteristics, the authors argued that the land-use - travel relationship was an artifact of an association between land-use and variety of social and demographic characteristics associated with travel; They suggested that land-use determined attitudes; higher density, for example, means smaller houses, lower incomes and other factors that affected one's attitude. Attitude in turn influenced travel behavior;' The authors concluded that land-use policies promoting 'high densities 'and more mixed use may 'not influence travel behavior unless residents' attitudes are also changed.

A study centered around household based trip statistics is by **Holtzclaw (1991)**, wlid studied data from several types of communities'with varying densities and land use mixes in the San Francisco region. Odometer readings and trip logs were used to determine reduction in automobile 'mileage 'due to higher residential 'density, neighborhood businesses, and improved transit service. The conclusion is that as the housing, population, and commercial densities decrease, and the transit service decreases, the vehicles miles traveled (VMT) per capita and per household increase. Doubling residential' or population density reduces' the annual auto mileage per capita or per household by 20 to 30 percent.

A detailed travel survey study was documented by **Ewing et al.** in 1994. Six communities in- Palm Beach County, Florida, 'were chosen for study based on their diverse development. Household travel data including trip frequency, mode choice, trip chaining, trip length, and. overall vehicular travel Were used to study 'the relationship between household travel, location and land use. The researchers concluded that households in the "sprawling" hon-gridded suburban community '(composed, mainly of single-family homes) had almost 66 percent more vehicle-hours thandid'a traditional gridded community with varied land use. Other communities fell between the extremes. The'authors-'concluded that higher density, mixed land use, and central location tended to be associated with reduced 'vehicle-hours of travel.

An article that encouraged further research was by **Steiner (1994).** This study documented literature on residential density and travel patterns. The author concluded that decreased usage of the automobile is possible in high&density residential" areas because of several factors:

1. High density puts destinations close together, making it possible to walk.

2. The greater number of people in an areas, the more an area is perceived to be safe for walking.

3. Certain types of people and households may be more. likely to live in high density residential areas.

However, like Crane, Steiner cautioned that often assumptions are made concerning the relationship between high-density neighborhoods and the residents' transportation choices which may or may not 'be true.' She indicated that many studies have not separated out factors such as income,' household size, life-cycle characteristics, etc., which also affect transportation choices. Steiner advocated further researchto sort. out the importance of the pattern of travel based on the above characteristics; 'only then can conclusions be drawn on which households might be willing to live in high-density areas and the extent. to which changes in land-use patterns reduces travel.

Handy in a 1991 article summarized the issues surrounding the. concept of travel in mixed-use neighborhoods. Proponents claim fewer and. shorter auto trips, more walking trips, and a greater sense of community in these developments. Yet critics and skeptics. indicate these claims are not proven, that people may not want to live in these neighborhoods, and that the entire conceptis simply not feasible. The author articulated a need to answer the underlying question of how neotraditional 'developments will relate to the 'larger settlement patterns. She concluded that the entire debate over the neo,traditional issue "is greatly in need of substantive arguments, of testing and exploration of issues at a much greater depth than has occurred to date."

<u>Summarv of Travel in 'Mixed Use Neighborhoods</u>

All of the studies in the above section detail, travel in mixed-use neighborhoods. **Table** 5 summarizes the key findings for each study and identifies relevant items to the research in this paper.

Most of these studies find some. sort of association between mixed-use neighborhoods and less auto travel. However, some authors (e.g.,, Kitamura; Crane; Steiner; and Handy)- urge caution because the issue is complex. They contend that studies' need to carefully factor out household and life-cycle characteristics before relevant comparisons can be made.

Weekend Travel

Weekend travel in the Puget Sound region was the topic of a 1971 PSCG report which indicated that "there is increasing concern that proper attention has not been given to recreational travel (primarily done on the weekends) as a factor in transportation planning." The study proposed a multi-phased concept for long-range planning of urban transportation facilities to serve the weekend travel demands of metropolitan areas. Recommended methods included a variety of modeling (due to limited availability of empirical data). The study did not report any results and only travel to major recreational areas were addressed.

A recent study from Japan **(Yai et al.** 1995) indicates that the volume of passenger vehicles for recreational traffic on weekends can be equivalent to that of weekday commuter traffic. This study, like the previous one, will develop recreational travel demand models. It will be used for trip generation and trip distribution using an aggregate regression model and a disaggregate model.

Voorhees and Associates, (1974) also proposed modeling to analyze weekend vehicular travel. The scope of the study was Sunday afternoon traffic on rural highways returning from recreational destinations to. urban areas. Some state and national data were used to calibrate the model, some output of which shown in Table 6. The authors concluded that weekend travel demand must be linked with weekday travel estimates for adequate highway design. They added that any "model is only as good as the input data. Therefore, a large amount of empirically derived data is necessary to simulate present travel patterns." They cautioned that good travel data for weekend analysis is 'lacking in many state planning agencies.

A more recent study on vacation travel was entitled "Weekend Travel:. America's Growing Trend" **(US Travel Data Center 1990).** Its focus was for round trips of at least 200 miles, multiple day (one to five night) trips taken over a weekend. Although geared toward the travel industry, some findings are illustrative of weekend travel in general. Information was obtained from the Data Center's National Travel Survey and indicated that between 1984 and 1989 total trips increased by 26 percent, while weekend trips increased by 34 percent. Table 7 shows trip characteristics and demographics for weekend vacation travel.

An empirical study exploring weekend traffic volumes was done in the Santa Monica Mountain area of southern California **(City of Los Angeles** 1978). Although most of the results are specific to that area (e.g., volume percentages for certain intersection approaches), this study introduced the concept of temporal distribution. The study demonstrated that both Saturday versus Sunday and time of day 'distributions would be 'interesting variables to explore.

Hu (1996) used the Nationwide Personal Transportation Survey for a study on travel behavior by day of week. Multitudes of figures and tables describe household characteristics, person characteristics, and trip characteristics for Saturday and Sunday travel. This information can serve as a benchmark for weekend travel in typical urban areas.

Table 5. Summary of Travel Studies on Mixed Use Neighborhoods

Author	Key Findings	Relevant Notes
Giuliano	Land use — transportation connection too weak to matter in terms of public policy	Based primarily on commuting research
Cevero and Landis	Land use can be important contributor to transportation trends.	Includes research on rail transit
Frank and Pivo	Average work trip length ending in a balanced area 29 percent shorter than work trips that end in unbalanced areas	
Pivo et al	Association between both density and balance and less auto use confirmed	
Bookout	Fewer cul-de-sacs, return to grid street pattern, and ped. and transit friendly neighborhoods will reduce vehicle trips or trip distances	Based on Kulash Study
Kulash	Traditional street network produces 57% less total VMT, shorter trips and works more efficiently than conventional suburb	Internal trips only, trip frequencies are fixed and local street traffic much higher for traditional network
McNally and Ryan	Neotraditional network has 10% less veh.-km and 27% less veh.-hrs traveled, and 15% shorter ave. trip length than conventional network	Trip frequencies are fixed

Table 5. **Summary** of Travel Studies
on Mixed Use Neighborhoods (Continued)

Author	Key Findings	Relevant Notes
Friedman, Gordon and Peers	Suburban areas generated 23 % more trips, had higher drive alone rates and had half the transit share of traditional communities	
Crane	Contradicts Kulash, McNally and Friedman. Says one cannot separate out many differences between suburban and traditional communities. Transportation problems may worsen in traditional communities because trip demand may go up. Therefore trip frequencies in network studies should not be fixed.	
Kitamura et al.	Land policies promoting high densities and more mixed land use may not influence travel behavior unless resident's attitudes were also changed.	
Holtzclaw	Doubling residential or population density reduces the annual'auto mileage by 20 to 30%	Did not correct for income
Ewing	Households in suburban community had 2/3 more veh.-hrs than a traditional community with gridded streets and varied land use.	Controlled for income & included chaining analysis
Steiner	Higher density residential areas make decreased usage of auto possible. Household and life -cycle characteristics need to be factored out	Advocates further research
Handy	Need to answer how mixed use developments will relate to larger settlement patterns	Advocates more research

Table 6. Weekend Travel Characteristics

Topic	Finding
Primary Weekend Trip Purposes:	Recreation: 33 % Social: 34 % Shopping: 10%
Average Trip Lengths:	70-100% longer for weekend trips than for weekday non-work trips

source: Voorhees and Associates 1974

Table 7. Weekend Vacation Trips

Topic	Response	Value
Main Purpose of Trip	Visit Friends and Relatives	45 %
	Outdoor Recreation and Entertainment	45 %
Travel Party Size	One	41 %
	Two	33 %
	Three	12 %
Presence of Children	Parties without children	78 %
	Parties with children	22 %
Income	Less than $35,000 per year	45 %
	More than $35,000 per year	39 %
Household Structure	Single adult, no children	19 %
	Single adult, with children	4 %
	Two or more adults, no children	40 %
	Two or more adults, with children	37 %
Household Size	One	19 %
	Two	29 %
	Three	22 %
	Four	19%
	Five or more	10 %
Age	Average	39 years
Sex	Male	51 %
	Female	49 %

source: US Travel Data Center, 1990

Finally; some- useful weekend 'travel data for this project were obtained, from Murakami (1996) who used data from the Nationwide Personal Transportation, Survey. Several tables listing weekday travel were redone, for weekend travel only and served. as an excellent reference for the research summarized in this paper. **Table** 8 shows general information about the three variables used in this research.

Summary of Weekend Travel

Table 9 shows the major findings of weekend travel studies. The -focus is mostly. on long distance recreational travel not influenced. by urban form. Hu and Murakami will serve as excellent base points from which to compare the characteristics of typical urban areas with those of mixed use neighborhoods. However, none of these studies addressed the issue of walking trips.

Literature Review Summary

This literature review has shown that travel is increasing, and that mixed-use neighborhoods may offer some transportation benefits. Many of these studies have shown that mixed-use or neotraditional neighborhoods are associated with less auto travel.

On the other hand, several authors urge caution and more research because of the issue's complexity. Household and life-cycle characteristics need to be carefully factored out before relevant comparisons can be made between, mixed-use neighborhoods and more suburban areas. Additional measures such as trip frequency and travel speed must be analyzed to portray travel patterns.

Non-work travel is gaining in magnitude and complexity. Trip chains are becoming increasingly important, and trip counting techniques (such as number of trips) must be modified to reflect the new transportation trends more accurately. Short walking trips are important in non-work travel in mixed-use'neighborhoods, as such, they should be included in the analysis.

Finally, weekend travel is an area that has received little research attention. Most modeling studies suffer from a lack of data upon which to calibrate the models. Extant empirical studies have not addressed mixed-use neighborhoods explicitly (including short walking trips).

THE DATA SETS

Introduction

This research was based on two data sets. First, a mixed-use neighborhood data set was collected by the Washington State Transportation Commission's Innovations Unit in November and December of 1991 as part of this study. Second, the Puget Sound Regional Transportation Panel Survey, conducted from September through November 1989 and obtained from the PSRC, was used as a reference data set. To enhance the validity of comparisons between the two data sets, the mixed-use data collection effort was designed for compatibility with the PSRC's panel survey methodology.

While this section focuses on the data collected from the mixed-use neighborhoods, the data collection methodology for both data sets is discussed briefly. The mixed-use data required considerable preparation for analysis, and the steps of this process are documented herein. Since both data sets are compared, differences between the mixed-use data set and PSRC data set are discussed.

Table 8. Data Comparison Topics from Murakami

Table Title	General Information
Average Weekend Trip Length by Purpose	4-18 miles
Average Weekend Trip Length by Mode	0.5-14 miles
Daily Person Trips per Household by Household Size	2-11 trips

source: Murakami 1996

Table 9. Summary of Weekend Travel

Author	Key Findings	Relevant Notes
PSGC, and Yai	Highlight need for weekend travel studies. Propose modeling to study weekend recreational travel demands	No results
Voorhees et al	Primary weekend trip purpose: social, recreation and shopping.	Recommend more empirical studies
US Travel Data Center	Provides trip characteristics and demographics.	Based on longer vacation trips only
City of LA	Not relevant	Use temporal distributions
Hu	Household, person, and trip characteristics listed for more typical urban areas	Good source for data comparison
Murakami	Average trip length by purpose and mode as well as trip frequency given for typical urban areas.	Good source for, data comparison

The Mixed-Use Data

The mixed-use neighborhood data set was obtained from ,a series of two-day travel diaries completed in November. 1992. Over 1,620 individuals in 900 households in the Kirkland, Wallingford, and . Queen. Anne neighborhoods in the greater Seattle region responded. A project report **(Zemotel et al.** 1993) details the data collection methodology, characteristics of the study neighborhoods, and preliminary data analysis.

Neighborhood Descriptions

Neighborhoods were selected for study because they had more than one distinct land use (residential as well as other uses), and because each was located in an area offering a range of mode choices. The location of each neighborhood is shown in, **Figure 1**.

Queen Anne, located a few miles north of downtown Seattle, was the smallest of the three study areas. The study area was roughly 0.5 mile by 0.7 mile, centered on Queen Anne Avenue, a busy. shopping street with supermarkets, banks, restaurants and retail shops. The rest of the study area was residential with a few scattered retail and office facilities. Queen Anne's streets form a grid pattern.

Wallingford is west of Interstate 5, a few miles north of downtown Seattle, and west of the University of Washington. The study area was approximately 0.75 mile by 1.25 miles long. The neighborhood's land use is diverse with parks, residential uses, and a variety of retail and commercial buildings. The main shopping area is along Northeast 45th Street and, to a lesser extent, along Stoneway Avenue North. The street pattern forms a grid.

Kirkland is a suburban neighborhood bordered by Lake Washington on the west and Interstate-405 on the east. The study area was the largest and was approximately 2.0 miles by 1.2 miles. The area includes a renovated downtown and a mix of housing types. Kirkland's shopping and commercial facilities are somewhat more scattered than those of the other study neighborhoods, but there are concentrations along Central Way and at the downtown 'core' where Central Way meets Lake Street Kirkland has a combination of a grid street pattern and curvilinear streets with cul-de-sacs, which is different from the strictly gridded streets of Wallingford and Queen Anne. Kirkland's land use pattern in many ways represents a transition between a mixed-use area and other suburban development.

Data Collection Process

Individuals in each neighborhood, were initially contacted through a random dialing phone survey. First, a range of demographic information was collected from each respondent. This- information included the number of vehicles owned, family size, and income. Information was also collected on each person (over the age of 15) surveyed. This information included age, sex, and whether the respondent was empioyed, a student, or neither. Respondents were then asked to participate in a travel diary survey. Those who agreed to participate were then sent a travel diary packet. Forty-three percent of the people contacted agreed to complete the travel diary. Among- this group 76 percent returned ,a completed diary resulting in an overall response rate of 33 percent.

Each family member over the age of 15 in the survey household was asked to fill, out a two-day travel diary describing every trip taken 'over that period; Information on each trip was to include purpose, travel mode, number of people in the vehicle; trip 'duration, and amount of time spent at the destination.

The Location Data.

The travel diary data focused on respondents' travel 'patterns.' However, as collected on the diary, travel origins and destinations were listed as only a set of addresses, an intersection;' or the name of a landmark. To make these data usable the information Was geocoded. The resulting data set contains more than 24,000 addresses, intersections, and landmarks. The Census' TIGER line file for all:. of King County was used for address matching. Computer software successfully, geocoded 65 percent of all the location with the remaining, location coded by hand. Ultimately' over, 96 percent of the locations "were successfully 'g&coded. The few locations that could not be coded involved a trip that was outside King County, bad information, or incomplete survey responses.

Panel Survey Data

The PSRC transportation panel survey was used as the source of comparative county-level travel characteristics. Since the PSRC data collection effort was started before the mixed-use survey project was initiated, the PSRC survey was used as the basis for the design of the mixed-use survey.

The PSRC panel survey was a major effort aimed at collecting data on the effect of transportation conditions and demographic characteristics on household travel behavior in urban areas. Only part of the PSRC survey effort (the first wave conducted in 1989). was used for this study. The data used for this study involved 663 households in King County making almost 12,000 trips (see Murakami and Watterson (1992) for detailed information on the survey methodology).

Identification of Trip Chains,

Since the 1970s, the emphasis in many studies of transportation behavior has shifted from analysis of individual trips to that of multipurpose trips or chains. This shift is due to the recognition that understanding chained, travel is crucial in understanding most individual travel behavior (Alder and Ben-Akiva 1979). A more. accurate view of urban travel accounts for sequential, multipurpose travel and assumes accessibility changes as a person moves from one trip origin to another.

The methodology used to organize the mixed-use and PSRC data into trip chains borrowed from previous trip chaining research. Examination of the literature suggests a chaining definition on the use of home or work as an anchor point.. Adler and Ben-Akiva's (1979) widely cited model of chain behavior was based on chains defined as 'trips to or from home. A link (which they called a sojourn) is a visit to any place remote from home. A combination of trips away from, home defined a trip tour (or chains). Southworth (1985) dividedchains into five types based on trips that started from home or work. Strathman and Dueker's (1994) analysis of the National Personal Transportation Survey (NPTS) used, a typology based on chains that started and ended at home. Hodge, while exploring multi-purpose travel in King County (the same area as this study), considered a chain to be' any set of trips that had home or work as an endpoint (199 1). The trip chain was considered broken if an individual stayed at a location longer than 90 minutes.

Each of the studies listed above started and stopped (that is anchored) trip chains at a home location and sometimes at a work location. For this research, 'chains were also anchored at home or work; However, this study, like Hodge's, also broke chains after an individual remained at a stop longer than 90 minutes. Breaking a chain after a time threshold served as a mechanism to clearly delineate the importance of the home and work trip anchors in determining trip chains. In addition, **Richardson and Young** argued that the use of temporal constraint serves to reduce the number of unrealistically long chains and could make the process of exploring travel more tractable (1982).

DATA ANALYSIS — WEEKDAYS

Overview

In this section, travel characteristics of the inhabitants of the mixed-use neighborhoods and the PSRC survey are explored. The measure of travel most commonly used in this paper is ***average daily travel mileage per person*** (over age 15). This figure expresses the average per-person mileage of all trips made in one day, based on all the survey respondents fitting into the category of interest.

The analysis begins by examining the geographical areas and general travel characteristics of the survey respondents. The relationship between household income, household category, respondent's age and sex, and the average daily mileage traveled is explored. The section also looks at transit, walk and bicycle trips.

Since most urban travel involves multi-purpose trips, there is also some focus on trip chaining behavior. Given the importance of nearby destinations to' the neotraditional concept, an identification of trip stops that were close to each respondent's household is also completed. Work travel is given separate consideration. This analysis looks at work chains, chain lengths, and work locations.

The data analysis then looks at the neighborhood-level travel patterns of the mixed-use respondents. This section examines the pattern of trips generated by local commercial establishments and bus stops. The trip length and travel characteristics of the mixed-use households and PSRC's King County households are directly compared. The analysis involves a number of household and income categories and analysis zones.

It should be reiterated that analysis in the weekday portion of this study compares the mixed-use data set with the PSRC 'data set and that both data sets, were adjusted for compatibility. Since the PSRC respondents were asked only to include trips five minutes or longer, only mixed-use weekday trips of more than five minutes duration are included in comparisons.

Geographical and Household Characteristics

Geographical Variables

Because this study was driven by the geographical location of households, analysis required development of a number of distance and zonal variables. Several geographic zones were created based on when the cities or census places in the county were initially developed **(Figure** 2). The first zones were the three mixed-use neighborhoods of *Queen Anne, Wallingford and Kirkland.* The city of Seattle is divided into *north Seattle.* Since *north Seattle* encompasses- the Queen Anne and Wallingford study areas, these areas were frequently compared. In the PSRC data sample 176 households, were randomly sampled in north Seattle. *The* next zone is *an inner ring,* and about 30 cities surrounding Seattle" that were developed in the 1940s, '50s and early '60s, and sampled 163 households. The *outer ring* includes both newer suburban developments and the remaining rural and unincorporated portion of King County, and sampled 248 households.

Household Characteristics

A summary of demographic characteristics of the mixed-use neighborhoods only and several King County analysis zones are shown in **Table 10.** The two mixed-use neighborhoods within Seattle are similar. The third mixed-use neighborhood, Kirkland, has a higher median age and considerably lower residential density. With the exception of income, North Seattle is much like Queen Anne and Wallingford. Inner and outer King County are also similar to each other and have larger household sizes and higher auto ownership levels than areas in Seattle.

General Travel Characteristics

Age

Both the mixed-use and PSRC surveys, elicited respondents' ages. **Table 11** compares average daily travel mileage per person for each survey in eight age categories.

Across the two data sets, the King County respondents generally traveled more miles per day than did their counterparts in the mixed-use neighborhoods. Individuals from the outer area groups tended to have the highest mileage, followed by the inner areas. The Kirkland neighborhood tended to fall between the other two mixed-use neighborhoods and the King County areas. Among age groups, the youngest and oldest groups had lower mileage than did those in the more middle-age categories. The higher mileage groups in the neighborhood of Queen Anne and Wallingford tended to be older than those in the other areas.

Income

Table 12 shows the daily average mileage per person related to. annual household income. The households were classified by low or high income with an income of $35,000 as the cutoff point.

For both the mixed-use neighborhoods and in King County suburban areas, individuals from the lower income households traveled less per day. Differences between lower and higher income individuals ranged from 1.9 percent (less than a mile a day) in the outer zone of King County to 23 percent (almost 8 miles day) for the Kirkland neighborhood. The PSRC survey respondents who lived in outer King County had a daily mileage that was high regardless of their income category.

The two mixed-use neighborhoods in Seattle (Queen Anne and Wallingford) also had considerably lower daily mileage per person than did the north Seattle households. The Kirkland respondents' mileage was greater than the other mixed-use neighborhoods but less than that of the inner and outer areas of King County. This perhaps reflects Kirkland's combination of mixed-use and suburban characteristics.

Table 10. Summary of Household Characteristics

Location	Average House-hold Size	Average Number Employees/ Household	Average Number of Vehicles/ Household	Median Age of Persons over 15	Percent Income over $35,000	Gross Density hh per Acre
Queen Anne	2.2	1.4	1.7	39	67%	7.6
Wallingford	2.1	1.3	1.6	37	56%	7.2
North Seattle	1.9	1.2	1.8	37	41%	5.4
Kirkland	2.0	1.0	1.9	47	61%	3.1
Inner	2.5	1.4	2.1	35	56%	1.2
Outer	2.7	1.4	2.2	37	55%	0.2
Urbanized King Co.	2.5	1.3	2.1	37	51%	2.0

Table 11. Average Daily Mileage Per Person by.Age **Group (Weekdays** only)

	15-17	18-24	25-34	35-44	45-54	55-64	65-98	All Age	*Total (n)*
Queen Anne	*19.0*	21.2	18.0	17.7	22.4	14.3	14.5	18.2	*670*
Wallingford	*9.5*	13.6	18.1	16.0	18.8	19.8	16.9	16.9	*594*
North Seattle	13.3	20.0	24.5	24.2	23.4	21.6	16.6	22.4	*581*
Kirkland	*12.7*	32.6	31.7	29.8	26.4	27.2	21.9	27.1	*589*
Inner	18.4	31.0	33.3	35.2	29.5	28.8	22.0	30.3	*659*
Outer	26.0	43.4	40.3	42.4	37.0	34.6	36.9	38.5	*924*

n = number of person days, italic = n less than 25

Table 12. Average Daily Mileage **Per Person by Income (weekdays)**

	Household Income Less Than $35,000 a Year	*(n)*	Household Income More Than $35,000 a Year	*(n)*	% Diff.
Queen Anne	14.5	*181*	19.7	*475*	26.2%
Wallingford	16.1	*231*	17.2	*353*	6.4%
North Seattle	20.3	*290*	24.3	*263*	16.5%
Kirkland	22.0	*184*	29.7	*386*	25.9%
Inner King Co.	27.6	240	32.2	*397*	14.3%
Outer King Co.	36.7	*346*	37.4	*549*	1.9%

n = number of daily person trips

Table 13. Average Daily Travel per Household **Category (Weekdays)**

	child (ren) under 6	child (ren) 6 - 17	one adult < 35	one adult 35 - 64	one adult 65+	two adults <35	two adults 35 - 64	two adults 65+	Total (n)
Queen Anne	19.9	20.0	6.5	10.7	19.5	19.6	16.9	18.2	671
Wallingford	16.9	17.9	21.1	16.4	*13.9*	15.5	17.5	17.1	595
North Seattle	29.0	21.7	19.2	19.9	*14.4*	23.0	22.2	17.1	636
Kirkland	28.2	29.3	*31.2*	23.4	24.2	32.6	30.4	21.0	591
Inner King	32.4	32.5	*46.3*	28.6	21.1	31.7	30.0	22.2	712
Outer king	45.2	37.1	*36.7*	33.4	42.5	36.6	37.9	34.0	998

n = number of person days, italics = n less than 25

Household Category

A detailed analysis of mileage was completed by examining travel as related to household category. The use of household categories attempted to remove any effect that household size and type may have on-daily travel patterns **(Table 13).**

Several patterns are visible in **Table 13.** For both data sets, households with. young children showed higher rates of daily travel. In the King County data, households with older children also traveled a larger number of miles per day. In the mixed-use neighborhoods, individuals from households with two middle-aged adults traveled as many miles per day as did individuals from households with small children. In both data sets, the lowest mileage was found in households with individuals 65 years or older. Across the data sets, King County respondents traveled more per day than did those from the mixed-use neighborhoods.

Sex

Table 14 shows the average daily trip mileage by sex for both automobile and bus modes. The mileages for the two modes is the averaged. total mileage traveled per day by a survey respondent on either transit or automobile. Some of the transit information should be interpreted with caution because of small sample sizes.

As seen in **Table 14,** men typically traveled more miles per day by automobile than did women. Among the various areas, Queen Anne and Kirkland saw the greatest difference in automobile between men and 'women. For transit mileage, the Queen Anne and Wallingford neighborhood showed minimal differences between the sexes. The North Seattle and Kirkland areas, on the other hand, had notably higher transit mileage.

Transit Use

Table 15 shows the relationship between transit and non-transit users in terms of daily mileage using several modes. A survey respondent is considered a transit user if they used transit for any trip during a day.

Table 15 shows that in Queen Anne, Wallingford and North Seattle transit riders traveled less miles per day than non-transit users. In the other areas the difference between transit and non-transit user was minimal. One interesting finding is the that non-transit users in the inner suburbs of King County traveled 8 percent less per day than transit users. Since the data is for weekdays, one possible reason for this situation is a long transit commute to the Seattle CBD.

Table 14.. Average Daily Mileage Per Person by Mode and Sex (Weekdays)

	Automobile					Bus				
	Male	*(n)*	Female	*(n)*	% diff	Male	*(n)*	Female	*(n)*	% diff
Queen Anne	20.5	*297*	16.9	*279*	19.7%	6.4	*48*	6.5	*80*	-1.6%
Wallingford	18.3	*217*	16.9	*293*	7.6%	6.6	*58*	6.6	*69*	0%
North Seattle	24.2	*250*	24.8	*69*	-2.4%	11.2	*43*	8.8	*63*	21.4%
Kirkland	28.8	*256*	24.2	*308*	16.0%	23.4	*14*	14.0	*33*	40.2%
Inner King	31.0	*299*	27.6	*352*	11.0%	16.1	*24*	17.7	*23*	-9.9%
Outer King	38.9	*444*	35.4	*455*	9.0%	22.2	*23*	25.0	*30*	-12.6%

N = number of person days

Table 15. Transit and Non-Transit Users Average Daily Mileage (Weekdays)

	Non-transit User	(n)	Transit User	(n)	Difference
Queen Anne	19.6	514	13.3	127	-47.4%
Wallingford	18.0	423	14.0	126	-28.6%
North Seattle	23.1	498	17.1	106	-35.1'
Kirkland	27.3	465	27.8	45	1.2%
Inner	29.7	618	32.3	47	8.0%
Outer	37.8	874	37.2	53	-1.6%

n = number of person days

Bicycle Use

In the mixed-use neighborhoods 94 weekday trips (0.9 percent) were by bicycle, while in King County 40 trips were by bicycle (0.3 'percent). Because these numbers were so small a further breakdown of the bicycle trips was not completed.

Pedestrian Trips

In the mixed-use neighborhoods 7,474 trips (11.3 percent of all trips) were by pedestrians while King County had 332 trips by pedestrians (3.6 percent of all trips). It must be recognized that these figures may underestimate the number of daily walk trips since they include only trips greater than five minutes in duration.' If short trips are included the number of walk trips increases. For example, for the mixed-use data,including all trips both above and below five minutes increased the number of walk trips from 11.3 percent to 15.9 percent. A distribution of walk trips by geographic area is shown in **Table 17.**

Table 17 clearly shows that the mixed-use neighborhoods of Queen Anne and Wallingford had the highest level of walking with around 18 percent of all trips on foot.

North Seattle and Kirkland had fewer walking trips with 7 to 9 percent of all trip on foot. In the suburbs of King County less than 3 percent of all trips were by foot.

The distribution of weekday pedestrian trips by trip purpose is shown in **Table 18.**

Table 18 shows that the most common purpose for walk trips is personal. This is reasonable since many personal trips include walking and running for exercise as well as simply recreational walking. Not including trips that return to the home, the most common purpose for walk trips, with the exception of Wallingford, was for work. For Wallingford, shopping' saw more pedestrian trips than did work.

Trip Chains

Each trip in the mixed-use and PSRC data set was assigned a chain and *link* variable. The first trip of the day for any respondent was always *chain 1, link* 1. If the next trip for that person started after a stay of less than 90 minutes and did not start from home that trip would be *chain* 1, *link* 2. Otherwise the next trip would be *chain 2, **link*** 1. This process continued until the next respondent or next day occurred in the data set. During this process, trips of ail duration were included; removing trips of under five minutes, as occurred in other parts of this analysis, could have influenced the continuity of some' of the chains. This probably had minimal impact on the analysis of chains since the PSRC respondents tended to include all trips, including those of five minutes or less. The percentage of chains by the number of stops is shown in **Table 19.**

Table 17. Walk Trips as a Percent of All Trips (Weekdays)

	Percent of Walk Trips	*n*
Queen Anne	18.1%	*610*
Wallingford	17.7%	*529*
North Seattle	8.8%	*246*
Kirkland	7.8%	*227*
Inner	2.8%	*90*
Outer	2.0%	*84*

n= number of trips(links)

Table 18. Walk Trips by Purpose (Weekdays)

	work	shop	school	personal	appoint-ment	home	N
Queen Anne	21.5%	13.9%	2.1%	34.1%	1.0%	27.4%	*610*
Wallingford	13.6%	17.6%	4.9%	31.6%	1.5%	30.8%	*529*
North Seattle	1.7.5%	10.2%	6.9%	35.0%	3.7%	26.8%	*246*
Kirkland	17.2%	12.3%	0.9%	42.3%	0.4%	26.9%	*227*
Inner	23.3%	12.2%	1.2%	40.5%	3.6%	21.4%	*90*
Outer	22.6%	10.7%	1.2%	40.5%	3.6%	21.4%	*84*

n= number of trips (links)

The three mixed-use neighborhoods showed similar chaining behavior. About 60 percent of all chains contained a single trip. These were mainly trips connecting home and work, or trips wherein travelers arrived at a stop and spent more than 90 minutes there. About a quarter of the chins Were two-link trips. This included common trips, such as dropping a child off at day-care on the way to work, as well as going from home to do some quick grocery shopping and then returning. This indicates that a significant number of the trips taken by the mixed-use respondents involved multi-purpose travel.

The data for north Seattle and the inner and outer suburban area of King, County indicated that about 70 percent of all chains were single-purpose trips that traveled directly from home or work locations without any intervening stops, This suggests that these residents have a lower rate of multi-purpose trips than do those living in the mixed-use neighborhoods.

The distribution of stops found in **Table 19** can be examined in more detail by looking at the average number of links (trips) per household per day. **Table 20.** shows the average number of links (trips) per household, while **Table 21** shows the average number of chains (under the definition used here, a single trip with an anchor at home or work is a chain).

As seen in the **Table** 20, the average number of links within each household type was similar for all locations. Across household types, those with children had the greatest number of stops per day, and households with one adult had the fewest.

Tables 20 and 21 suggest that respondents from both the mixed-use and King County had similar travel patterns in terms of the number of stops and the number of chained trips made per day. This is reasonable considering that travel demands on individuals in any type of area should also be similar. Individuals still need to travel to shop for groceries or buy clothes-regardless of where they live.

The average number of trip links per chain can be derived by combining Tables 20 and 21; the ratio **is** shown in **Table 22.**

Table 22 shows that the majority of all chains have one or two links or stops. Seniors have consistently more links per chain.

The nature of the survey respondents' chaining behavior can also be explored by analyzing the length of the trip chains as classified by the beginning or the ending link. For **Table** 23, the data from the three mixed-use neighborhoods are combined.

As seen in **Table 23,** for both **the** King County and mixed-use data, chains initiated or finishing at home are longer than those started elsewhere. Trips ending at work in the King County data were about 'as long as trips ending at home. However, in the mixed-use data, trips ending at work were notably shorter than trips ending at home, which suggests that mixed-use respondents made more stops coming from work than they did traveling to work.

Further investigation of chain length can be completed by examining the starting and ending purpose of each chain **as** shown in **Table 24.**

Table 19. Distribution of Number of Links (%) in a Trip Chain (Weekdays)

	1	2	3	4	5	6	7	8	9+
Queen Anne	61.1	26.0	7.8	2.9	1.2	0.6	0.3	0.1	0.2
Wallingford	61.1	26.0	7.9	2.9	1.1	0.5	0.3	0.1	0.1
North Seattle	69.3	20.2	6.2	2.5	1.0	0.5	0.2	0.1	--
Kirkland	58.1	26.4	9.1	3.6	1.6	0.6	0.3	0.2	--
Inner King	69.5	18.8	6.6	2.9	1.4	0.6	0.2	--	--
Outer King	68.2	18.8	7.3	2.9	1.2	0.6	0.4	0.2	0.4
All King County	72.2	17.7	5.6	2.3	0.9	0.4	0.2	0.1	0.1

Table 20. Average Daily Trip Links (Trips) per Household (Weekdays)

	Household Type			
	With child(ren)	1 Adult	2+ Adults	Senior
Queen Anne	12.9	5.2	10.8	6.9
Wallingford	11.5	5.3	10.4	6.9
North Seattle	10.7	4.7	10.6	7.2
Kirkland	11.4	5.2	11.6	7.0
Inner	12.0	4.7	9.6	6.8
Outer	11.3	4.1	9.2	7.7

Table 21. Average Daily Trip Chains per **Household** (Weekdays)

	Household Type			
	With Child(ren)	1 Adult	2+ Adults	Senior
Queen Anne	7.8	3.5	7.1	3.5
Wallingford	6.7	3.4	6.6	3.7
North Seattle	7.6	3.3	7.5	4.5
Kirkland	6.6	3.5	7.1	3.6
Inner	8.2	3.5	7.1	4.5
Outer	7.8	3.3	6.5	4.2

Table 22. Average Daily Trip Links per Chains per Household (Weekdays)

	Household Type			
	With Child(ren)	1 Adult	2+ Adults	Senior
Queen Anne	1.66	1.47	1.52	1.96
Wallingford	1.72	1.57	1.57	1.87
North Seattle	1.41	1.42	1.41	1.61
Kirkland	1.72	1.49	1.64	2.09
Inner	1.47	1.37	1.36	1.52
Outer	1.45	1.24	1.43	1.82

Table 23. Average Chain Length in **Miles** by Initial or Terminating Purpose (Weekdays)

	Beginning				Ending			
	Mixed	*(n)*	King	*(n)*	Mixed	*(n)*	King	*(n)*
Home	7.8	*5309*	10.4	*3658*	7.5	*5292*	9.9	*3593*
Work	6.3	*1810*	10.2	*1828*	5.1	*1847*	9.4	*1850*
Other	5.5	*1791*	7.0	*2250*	5.3	*1771*	8.5	*2291*

(n) = number of person chains

Table 24. Average Chain Length by Initial and Terminating Purpose

	Home				Work				Other			
	Mixed	*(n)*	King	*(n)*	Mixed	*(n)*	King	*(n)*	Mixed	*(n)*	King	*(n)*
Home	8.3	2795	13.0	873	7.1	1289	11.4	1194	6.1	II92	6.9	1509
Work	5.9	*1121*	*10.8*	*1192*	*5.3*	*176*	*12.2*	*SO*	3.4	443	6.1	543
Other	5.5	1320	8.7	***1525***	3.4	303	7.4	573	7.1	***148***	10.3	***193***

(n) = number of person chains

For the mixed-use respondents, the longest chains are those that (1) begin and end at home; (2) begin at home and end at work; and (3) begin and end at other locations. The shortest chains are those that (1) begin at work and end at another purpose; or (2) begin at another purpose and end at work. This situation indicated that non-discretionary, **work-based** trips tended to be longer than more flexible, discretionary trips for other purposes (e.g., shopping, personal reasons) The longest chains were those that both started and ended at home. This category includes the greatest number of trips, and it probably includes many shopping trips from home wherein the respondent stayed less than one hour at the trip destination. Stops of less than 90 minutes would not create a new chain under this project's definition.

As seen in both **Tables 23 and** 24, the chains completed by the King County inhabitants were generally longer than those of the mixed-use inhabitants, but they followed the same patterns between purposes. However, one difference is that discretionary trips by King County inhabitants from work to other. destinations were relatively longer. This suggests that the King County inhabitants may be more likely to complete errands as they travel from work or that in the suburbs you need to travel farther.

Table 25. Percent of Trip Stops By Distance from Households (Weekdays)

	Distance of Stops from Household Location		
	1.0 Miles	1.5 Miles	2.0 Mile
Mixed Use	17.4%	25.4%	38.7%
King County	4.5%	11.6%	18.2%

Trip Stops

Given the neotraditional movement's emphasis on trips to locations near home, one factor of interest is how many trip destinations are **within a short distance** from home.. **Table** 25 addresses trip ends that are less than two roadway. miles from each respondent% household.

This table clearly shows that the respondents in the **mixed-use neighborhoods** made almost twice as many trips to stops within 2 miles of home than did the King County respondents. The difference between the data sets is especially evident for trips less than one mile from home.

Work Travel

A number of studies have indicated that understanding urbandaily **travel** behavior requires consideration of, not only an individual's household location, but his or her workplace location as well. Hanson, for example, using travel diary data from a **Swedish** city, concluded that many households' daily trips were tied to the journey to **and from** the work place (I 980). **Hodge, using travel diary data** collected in King **County,** concluded that, "The journey to work remains a critical element of urban trip making, both as organizer of discretionary travel and household activities" (199 1).

The following tables highlight the importance of the work trip in daily travel patterns and their role as part of multi-purpose trips. **Table 26** shows the percentage of ***links*** (trips) that involve a work stop.

Table 26. Percent of all trip links involving a work stop (Weekdays)

	All Day	AM[1]	PM[2]
Queen Anne	33.9%	53.4%	32.8%
Wallingford	30.7%	57.5%	36.6%
Kirkland	29.1%	55.7%	30.3%
King County	31.6%	50.8%	35.5%

[1] Any trip link that starts between 6 and 9 A.M. [2] Any link that starts between 3 and 6 P.M.

During the morning commute, more than one half of all trip links involved a work stop while about a third of all the evening commute trip links involved a work stop. The King County respondents' distribution of links per day is not notably different from that of the mixed-use respondents.

Table 27 shows the percentage of ***chains*** that involve at least one work stop. If trip ***chains,*** involving a work stop are examined, **as** in **Table** 24 above, the predominance of the work trip is more apparent. Between 40 and 50 percent of all daily trip chains include a work stop. During both the morning and evening commute, this percentage increases to over 50 percent.

The contribution of the work trip to daily travel can also be explored by looking at average mileage for both work and non-work chains. **Table 28** shows length for work chains, and **Table** 29 shows length for non-work chains. As seen in the table, except for the senior households category (which tends to include retired individuals with few work trips, and small survey sample sizes), King County work chains were slightly less than twice the length of the mixed-use chains.

Table 27. Percentage of all trip Chains involving a work stop (Weekdays)

	All Day	AM[1]	PM[2]
Queen Anne	48.4%	56.2%	57.6%
Wallingford	43.6%	59.3%	52.9%
Kirkland	41.9%	57.1%	50.9%
King County	44.8%	55.0%	51.9%

[1] Any trip chain that starts between 6 and 9 A.M. [2] Any trip chain that starts between 3 and 6 P.M.

Table 28. Average Daily Trip Mileage Per *Work* Chain

Household Type	Mixed		King County	
	Mileage	*(n)*	Mileage	*(n)*
With Children	4.9	*481*	9.2	*703*
1 Adult	4.8	*212*	7.1	*226*
2+ Adults	4.9	*706*	9.1	*912*
Senior	5.1	*61*	5.1	*45*

(n) = number of daily person chains

Table 29. Average Daily Trip Mileage Per *Non-work* Chain

Household Type	Mixed		King County	
	Mileage	*(n)*	Mileage	*(n)*
With Children	6.0	*1182*	10.1	*1512*
1 Adult	6.4	*516*	8.5	*279*
2+ Adults	5.8	*1303*	10.1	*1412*
Senior	7.4	*403*	9.5	*470*

(n) = number of daily person chains

As shown in **Table 29,** the mixed-use residents' non-work chains had about 40 percent less mileage than those of King County. A comparison of **Tables** 28 **and** 29 reveals that work chains typically had **slightly** lower mileage than non-work chains.

Regional Work Trips

One concern when comparing the mixed-use and King County data was confounding effects due to differential accessibility to Seattle's Central Business District, (CBD). The CBD is a major employment center for King County, as **such it** can be expected to attract a large number of work trips. Both Queen Anne and Wallingford are close to the CBD, Queen Anne is about two miles **and** Wallingford four miles away. This proximity raised concerns that any average trip length for these two neighborhoods would be shorter **than** other locations simply because work trips to the CBD would reduce the average trip length. These shorter work trips potentially could obscure some of the transportation effects related to mixed use.

As a means of investigating the **CBD's** capture of work trips, the location of each respondent's workplace was identified for both the mixed-use and King **County data. Table** 30 shows the percentage of work trips that remained in the same areas as the household location, and those that **traveled** to the Seattle **CBD and** to other zones. It is apparent from **Table** 30 that, the Seattle CBD is indeed a significant **generator of** work travel for Queen Anne and Wallingford. The CBD also attracts the same level of work trips from the north

Seattle zone. This finding is particularly relevant to this research because- the north Seattle study area includes the Queen Anne and Wallingford neighborhoods. Because of the equal percentage of work trips traveling to the CBD from each of these areas, we conclude that differences in average trip lengths between these areas are probably not unduly influenced by travel to the CBD.

Table 30 indicates that Seattle's CBD is a major location for work sites for King County's inner and outer zones. This is reasonable given the large size of these areas. However, as expected, most of the work sites for these two zones remained internal to the areas. The majority of the work locations for the Kirkland residents remain within the inner King zone.

Household Location and Commercial Establishments

Since each mixed-use household address was geocoded to a latitude and longitude, it was possible to determine each household's distance from commercial streets. This information made it possible to relate travel behavior of individuals to the accessibility to local goods and services. Accessibility was measured by the straight line distance between each household and the nearest commercial street. Commercial streets were selected based on concentrations of establishments providing goods and services used on a routine basis, including grocery stores, convenience stores, restaurants, dry cleaners, and drug stores.

Table 30. Work Trip Destinations (%)

Location	Within Location	To CBD	To North Seattle	To Inner King	To Outer King
Queen Anne	10.5	30.9	41.6	11.5	4.5
Wallingford	10.4	24.8	46.4	11.4	5.2
Kirkland	14.3	11.6	6.4	52.9	16.5
North Seattle	42.0	31.0	42.0	8.4	6.1
Inner King	52.7	12.6	9.2	52.7	10.5
Outer King	44.5	6.8	4.1	31.0	44.5

One tenet of the mixed-use movement is that nearby commercial establishments reduce the need to drive. One test of this idea is to compare levels of walking for mixed-use residents living at different distances from commercial areas. **Figure 3** shows the percentage of shopping trips that 'were completed on foot by households at five different distances from the commercial streets. This analysis includes only shopping trips that'have at least one trip end within a census tract that includes the mixed-use neighborhoods. As expected, the figure indicates that the farther mixed-use inhabitants live from a commercial street, the less likely their shopping trips will be on foot (and more likely in an automobile). This trend is particularly noticeable for the Queen Anne and Wallingford data. Over 65 percent of the residents from Queen Anne and 50 percent of those from Wallingford, who also lived within

0.1 mile of a commercial street, walked to shop. In contrast, fewer than 25 percent of those respondents who lived more than 0.2 mile from commercial establishments walked. (These trips could be going anywhere -not just to the local commercial street).

The Kirkland data showed a less obvious trend because of low numbers of walk trips and small survey sample sizes. Kirkland also had a more dispersed pattern of commercial activity than did the other two mixed-use neighborhoods, rendering any patterns less obvious.

The same analytical process was applied to recreation and personal trip purposes (**Figure** 4). Personal and recreational purposes include eating and drinking, pleasure trips, and family/personal business. As seen in the figure, the overall: relationship between walking trips and distance is also noticeable for recreation/personal trips. Since many of these purposes involve commercial establishments, it is not surprising that this level of walking shows a similar trend to shopping purposes.

Travel Mileage

Travel distance information from the **PSRC's** King County data was compared to data from the mixed-use neighborhoods. During this stage of analysis, an effort was made to control for sample bias, which was achieved by comparing travel mileage between similar household types and incomes. Because of small sample sizes, various categories were aggregated, and different analysis zones were used.

The average daily mileage by mode for Queen Anne and Wallingford combined (the Seattle mixed-use neighborhoods), Kirkland; north Seattle; and the inner and outer areas (the King County suburban **areas)** is shown in **Figure** 5. For all modes the following progression was observed: the Seattle mixed-use neighborhoods had the lowest mileage per day, north Seattle the next lowest, followed by Kirkland. The King County suburban areas had the highest daily mileage. Across modes, automobile use had the highest mileage. For transit the difference in average mileage for the two mixed-use neighborhoods and the King County suburban areas was 14 miles per day. For automobile use, this difference was almost 16 miles a day.

Figure 6 compares average daily travel mileage per trip by purpose. Again, there was a notable progression of trip mileage: trip length increased from Seattle mixed-use to north Seattle to Kirkland to suburban King County. In most cases, the Queen Anne + Wallingford mixed-use respondents traveled half the distance per trip than did those living in suburban King County. Across purposes, work trips had the highest average mileage, and shopping trips had the lowest trip mileage.

This average daily travel information can be subdivided by income. Since it was shown previously that daily mileage varies with household income, daily average mileage was separated into higher and lower income categories. **Figure** 7 shows the travel mileage for individuals from households with high and low incomes. Again, the Seattle area **mixed-**use neighborhoods showed the lowest mileage, and the King County suburban areas showed the highest. Those from households with lower incomes consistently traveled fewer miles per day than those from higher income households.

The travel mileage data can be broken down in more detail by location. **Figure 8** shows some of the same data as above, but disaggregated into the three mixed-use neighborhoods and the three King County zones. As with the previous figures, the Seattle mixed-use neighborhoods had the lowest daily person mileage, and the suburban King County areas had the highest. The Kirkland mixed-use neighborhood respondents had higher mileage than other mixed-use neighborhoods and north Seattle, but lower mileage than the King county suburban zones. This finding supports the idea that Kirkland is a transitional neighborhood between mixed land use and traditional suburban land use.

The results depicted in **Figure** 9 support some of the earlier findings in that individuals from households with children traveled the most and that those from households with seniors traveled the least. Those who lived in the Seattle area mixed-use neighborhoods consistently traveled fewer miles than the respondents from the King County data sets. In every case, the two Seattle mixed-use neighborhoods also had a lower average mileage than similar households in north Seattle.

Table 31 summarizes average daily travel mileage for several locations, household types, and two income levels. With the exception of categories with a small sample size, respondents from the Seattle mixed-use neighborhoods (Queen Anne and Wallingford together) had the lowest mileage for each household type and income category. North Seattle was the next lowest, followed by the inner King County cities, and then outer King County. Except for the senior households category (characterized by a small sample size), the higher income households had higher average daily mileage than their lower income counterparts.

Travel Time

As noted in the literature search, Gordon and Richardson (1994) pointed out that while work trip distances have increased, so have travel speeds, confirming a finding supported by this data analysis. Hupkes (1982) summarized trip rates and travel times for the

Table 31. Average Daily Travel Mileage by Househoid type and Annual Household Income (Weekdays)

	< $35,000		> $35,000	
With Child(ren)	miles	*(n)*	miles	*(n)*
Queen Anne + Wallingford	13.13	*96*	15.26	*663*
North Seattle	25.88	*44*	26.93	*96*
Inner	30.17	*79*	34.20	*189*
Outer	36.73	*133*	41.45	*242*
One Adult				
Queen Anne + Wallingford	16.53	*183*	17.56	*100*
North Seattle	20.53	*61*	18.15	*12*
Inner	30.85	*38*	36.45	*16*
Outer	37.23	*39*	28.00	*10*
Two Adults				
Queen Anne + Wallingford	11.75	*264*	15.48	*669*
North Seattle	20.58	*117*	24.49	*140*
Inner	27.34	66	31.88	*166*
Outer	37.85	1 1 7	36.64	*279*
Senior				
Queen Anne + Wallingford	12.04	I53	16.17	98
North 'Seattle	17.27	60	11.69	I O
Inner	23.79	56 .	21.55	*21*
Outer	38.04	50	28.63	19

(n) = number of daily person trips

U. S. and European countries and reported the average daily travel per person to range from 65 minutes to 84 minutes. The U. S. travel time in Hupkes' paper was 83 minutes for 1965/66 and was an average of 44 urban areas. Purvis (1994) calculated an average for the San Francisco Bay Area of 82.5 minutes per person in 1990. These observations seem to be confirmed the data analysis reported in **Tables 32, Table $3** and **Table 34. These** tables also show that substantial differences in daily travel distances among areas analyzed 'were not maintained when travel time was taken into account.

Table 32 indicates that for all ages all areas were clearly similar in the number of minutes spent traveling per day. Of all the age groups, the 18- to 24-year-olds in Queen Anne, Wallingford and outer King County tended to spend the most time traveling1 For the remaining age groups, those in the middle ages categories had longer travel times. The Seattle area average of about 90 minutes compares fairly well with the Bay Area when you consider that the Seattle survey collected no travel data from those younger than age 16 and the Bay Area started with age 5. NPTS (1995) reports shorter and fewer trips for these younger people and leaving them out raises the average travel time for those remaining.

Table 32. Average Daily Minutes of Travel Per Person by Age Group (weekdays)

	15-17	18-24	25-34	35-44	45-54	55-64	65-98	All Ages	Total (n)
Queen Anne	*89*	111	90	92	99	81	81	91.8	670
Wallingford	*84*	96	92	93	90	*88*	83	91.1	594
N. Seattle	89	85	93	88	89	78	75	86.2	596
Kirkland	99	81	86	98	100	96	80	90.1	589
Inner King	*61*	96	88	99	88	89	82	89.6	665
Outer King	57	109	95	94	92	96	100	93.8	925

n = number of person days, italics = n less than 25

Table 33. Average Daily Minutes of Travel per Household Category (weekdays)

	child < 6	child 6 - 17	one adult <35	one adult 35 -64	one adult 65+	two adults <35	two adults 35 -64	two adults 65+	Total (n)
Queen Anne	88	97	75	90	66	103	90	91	671
Wallingford	81	85	100	100	*87*	93	102	79	595
North Seattle	88	81	89	86	*54*	93	88	77	596
Kirkland	83	88	*76*	91	83	90	105	81	591
Inner	102	81	*83*	82	82	*88*	107	94	665
Outer	95	88	*86*	87	145	73	97	90	925

n = number of person days, italics = n less than 25

Table 33 is interesting in the variability, as well as the similarity apparent among household trips in the mixed-use and King County areas. In a number of age categories, individuals from the outer suburbs had the longest time travel (one adult **65+,** children under six) but for another types of household this area had among the shortest travel times (two adults < 35). The Wallingford neighborhood had the longest travel times for the several household types (one adult < 35, one adult 35 - 64) but among the shortest for households **65+.** The Queen **Anne** neighborhood had the longest travel time for households with two adults 35-65 but the shortest for one adult 65 +.

Table 34 indicates that the great difference in travel mileage between the'mixed-use neighborhoods and the King County area is not nearly as apparent as the difference in travel **times.** The average speed for each area shows **significantly lower** travel speeds for the Queen Anne and Wallingford respondents compared to other areas. Given 'that these areas had a higher use of the slower transit, bike and walk modes; and higher **levels** of congestion, this finding is reasonable.

Table **34.** Average Daily Time Vs Average **Daily Travel** Miles (Weekdays)

	Average Daily Travel Minutes	Average Daily Travel Mileage	Average Travel Speed (MPH)
Queen Anne	92	18.2	11.9
Wallingford	91	16.9	11.1
North Seattle	86	22.4	15.6
Kirkland	90	27.1	18.1
Inner	90	30.3	20.2
Outer	93	38.5	24.8

DATA ANALYSIS — WEEKEND TRAVEL

Overview

The previous section detailed weekday travel characteristics of respondents in both the mixed-use neighborhoods and in greater Seattle. While the journey to work still dominates transportation research, travel for shopping, as well as family and personal business, is. the f&test **growing element** of household vehicle miles traveled **(Comsis 1994).** Weekend travel primarily consists of these **categories,** and the . potential transportation benefits for mixed-use residents who can shop nearby are **intuitive.**

This section looks at weekend travel from the mixed-use survey. While no comparisons could be made with the PSRC data (wherein no weekend data were collected), descriptive statistics regarding weekend travel for the three mixed-use neighborhoods are presented. General travel characteristics, variations between **time** of day, and Saturday versus Sunday, as well as a separate look at short walking, trips, **provide** insight into the weekend travel patterns-of mixed-use respondents.

Because **only** the mixed-use neighborhood data are used for this section, the analysis includes all trips made by survey respondents, **including those** trips under five minutes in length. -Again all survey respondents are over age 15 years.

Households

There were 775 people living in almost 450 households providing weekend travel data for this study **(see Table 35)**. In general, the demographics of these households are comparable with the mixed-use households described earlier; the weekend data are merely a subset of the overall data set. As before, these data do not evaluate children under 15 years of age because they did not till out the travel diary surveys.

Table 35. Number of Hquseholds and People with Weekend Trips

	Number of Households	Number of Participants
Queen Anne	146	257
Wallingford	156	283
Kirkland	144	235

General Travel Characteristics

Basic Trip Information

A total of 5,699 weekend trips were taken by respondents in the three neighborhoods. **Table 36** depicts the trip distribution by neighborhood and day.

Trip Purpose

Distribution by trip purpose is shown in **Figure 10.** Unlike weekday travel, trips for school and work accounted for less than seven percent of, all trips. Thus,, they are 'not considered to be a factor on weekends. Trips for shopping, personal, and "home" accounted for more than 90 percent of all trips. Trip purposes by percentage were generally similar across the three neighborhoods.

Trip Mode

The predominant modes of choice in all three neighborhoods for weekend travel were either car or walking **(Figure 11).** Since less than five percent of all trips utilized a bus, bike or "other" mode, later analysis involving travel modes will include only car and walking trips.

The corresponding percentages for auto and walk travel are displayed in **Table 37**. While all three neighborhoods chose the auto predominantly as a travel mode, Queen 'Anne and Wallingford saw high percentages of walk trips, while Kirkland had only half the percentage walk trips of the other two neighborhoods.

Table 36. Weekend **Trip Information**

	Total number of trips	Number of Saturday trips	Number of Sunday trips
Queen Anne	2036	1119	917
Wallingford	1946	1062	884
Kirkland	1717	948	769

Table 37. Weekend Auto and **Walk Percentages**

(% of trips)	Auto	Walk
Queen Anne	76.2 %	18.9 %
Wallingford	75.5 %	18.8 %
Kirkland	89.1 %	9.1 %

Trip Length

Trip length is among the most frequently used measures **of travel.** The overall average trip length **in** miles for each of the three neighborhoods is shown in **Table 38.** Queen **Anne and** Wallingford had similar numbers, while Kirkland's average length was somewhat longer. Because the average lengths for **the** two predominantmodes (walking and auto) was so different, individual averages are provided as well.

Beyond average trip length, the distribution of trip lengths in the three neighborhoods is also of interest insofar as it is distinctly different. **Figure 12, Figure 13,** and **Figure 14 are** trip length histograms for each neighborhood. Queen Anne had many trips under one-half mile, with very few longer trips. Wallingford's histogram was less angled, but still indicated an emphasis on shorter trips. Kirkland however, beyond the very short trips; and saw a resurgence of trips at the **4-mile** mark, and again at the **10-mile mark.**

Trip Duration

Average weekend trip duration varied from 16.7 minutes for Queen Anne to 19.3 minutes for Wallingford. The Kirkland average duration was between the two at **18** minutes. As with the weekday data, the time duration of trips 'in these areas, due to increase **speeds,** show less variability than the distance in miles. Average **auto** trip duration is listed in **Table 39 (walking** trips are addressed. later). Queen Anne respondents spent the least time traveling by car for each trip. Yet as indicated in the second part 'of **the table, Queen** Anne residents spend the most amount of time traveling on a daily basis. This is **consistent** with the average daily travel minutes for weekday travel, and -concurs with later **findings that** 'Queen Anne residents travel more frequently than those living in the other mixed **use neighborhoods.**

Table 38. Average Weekend Mileage Per Trip

	Ave. Trip Length	Ave. Auto. Trip Length	Ave. Walk Trip Length
Queen Anne	3.9	4.5	0.3
Wallingford	4.0	4.9	0.5
Kirkland	5.1	5.6	0.4

Table 39. Average Minutes of Travel

	Per trip (autos only)			Per day (all modes)	
	Weekend	Saturday	Sunday	Weekend	Weekday comparison
Queen Anne	16.3	16.3	16.2	94	92
Wallingford	19.5	19.4	19.7	89	91
Kirkland	17.9	17.8	17.9	90	86

Total Distances Per Day

The average total distance per person per day is shown in **Table** 40. Kirkland respondents had 20 percent longer distances than did Queen Anne and Wallingford respondents. This may correspond to the longer individual trip distances seen in **Table 38.** Yet because the average duration was longer, the general travel speeds are somewhat higher in Kirkland, as noted above. This confirms patterns seen in the weekday analysis where Kirkland had the highest travel speeds of the three mixed use neighborhoods.

The average total distance per household per day is shown in **Table** 41. Wallingford households in general traveled the least, while residents in all three neighborhoods traveled much less on Sunday than on Saturday.

Freauencv

This measure is indicated by trips per person per day or. by trips per household per day. **Table 42** shows that the overall frequency is not significantly different among the three neighborhoods, although Queen Anne residents traveled most often. All residents tended to stay home more often on Sunday.

, Table 40. Average Daily Mileage Per Person (Weekend)

	Weekend	Saturday	Sunday
Queen Anne	21.5	24.7	18.1
Wallingford	18.3	19.5	17.0
Kirkland	24.5	27.0	21.7

Table 41. Average Daily Mileage Per Household (Weekends)

	Weekend	Saturday	Sunday
Queen Anne	36.8	42.6	30.8
Wallingford	31.3	33.5	28.9
Kirkland	37.7	42.4	31.5

Table 42. Average Weekend Trip Frequency

	number of trips per hh		number of trips per person	
	Saturday	Sunday	Saturday	Sunday
Queen Anne	10.5	8.9	6.1	5.2
Wallingford	8.9	7.3	5.0	4.2
Kirkland	8.4	7.2	5.2	4.7

Because mixed-use neighborhoods may encourage more walk trips, it is important to study frequency by mode **(Table** 43). Auto trip frequencies were very similar, but a difference is clearly apparent in the walk trips per person per day. Kirkland saw only half the frequency of the two mixed-use neighborhoods.

Number of people in party

The average number of people in a party for each trip varied from 1.60 for Wallingford, to 1.70 for Kirkland to 1.73 for Queen Anne. The distribution shows very' similar behaviors among the three neighborhoods, with more than 80 percent of all trips taking place either alone or with one other person.

Chaining Information

As people link more of their travel together, traditional travel measures such as number of trips may no longer reflect the amount of travel accurately. Calculating the number of links per chain provides a better measure of the **efficiency** of a resident's travel. Tabular results **are** shown in **Table** 44, while the distribution for links 'per chain is shown in **Figure 15.** For all three neighborhoods, about half of all trips had more than one link.

Table 43. Average Daily Trips Per Person by Mode (Weekend)

	Automobile Trips			Walking Trips		
	All Wknd	Sat.	Sun.	All Wknd	Sat.	Sun.
Queen Anne	4.31	4.70	3.90	1.07	1.04	1.10
Wallingford	3.48	3.79	3.17	0.86	0.91	0.82
Kirkland	4.43	4.70	4.14	0.45	0.44	0.46

Table 44. Number of Links Per Chain (Weekend)

Queen Anne	1.88
Wallingford	1.68
Kirkland	1.79

Data Comparison

Dav of Week

The travel patterns of mixed-use residents were not necessarily the same as opposed to Saturday and Sunday. The top part of **Table** 45 shows a summary of several travel measures for the two weekend days. In general, travel distance decreased on Sunday (except for the average distance per trip in Wallingford). Travel frequency decreased in all three neighborhoods on Sunday. Travel duration and efficiency (links per chain) remained relatively constant over the weekend.

The bottom portion of **Table** 45 lists compatible travel measures for the same residents on an average weekday. Trip distance (average trip length) and duration were similar from weekdays to weekends, while the number of trips and distance per person per day appeared to increase on the weekends.

There was very little variation in trip purpose between Saturday and Sunday. As indicated in **Table** 46, respondents from all three neighborhoods did a significant amount of travel for shopping and personal purposes. Kirkland saw a 50 percent drop in work trips between Saturday and Sunday.

Table 45. Travel Measures by Day of Week

	Distance per person per day	Distance per hh per day	Distance per trip	Minutes per trip	Trips per person per day	Links per chain
Saturday						
Queen Anne	24.7	42.6	4.2.	16.8	6.1	1.9
Wallingford	19.5	33.5	3.9	19.2	5.0	1.7
Kirkland	27.0	42.2	5.4	17.9	5.2	1.8
Sunday						
Queen Anne	18.1	30.8	3.5	16.5	5.2	1.9
Wallingford	17.0	28.9	4.1	19.4	4.2	1.6
Kirkland	21.7	31.5	4.7	18.1	4.7	1.8
Average Weekday						
Queen Anne	18.7	31.9	4.0	17.0	7.2	1.7
Wallingford	17.1	28.1	3.8	17.4	6.7	1.7
Kirkland	28.0	45.3	4.9	17.3	10.0	1.8

Table 46. Trip Purpose by Day of Week (% of Trips on that Day)

	Work	Shop	Personal	Home
Saturday				
Queen Anne	6.2 %	20.9 %	39.9 %	32.2 %
Wallingford	7.0 %	19.8 %	35.7 %	36.8 %
Kirkland	6.3 %	22.6 %	37.7 %	32.7 %
Sunday				
Queen Anne	5.9 %	19.7 %	38.5 %	35.7 %
Wallingford	7.1 %	17.5 %	36.1 %	38.6%
Kirkland	*3.0 %*	22.9 %	39.0 %	35.1 %

Italics = n less than 25

Table 47. Trip Mode by Day of Week (Percent of Trips on that Day)

	Auto	Walking
Saturday		
Queen Anne	77.3 %	17.1 %
Wallingford	76.0 %	18.3 %
Kirkland	89.8 %	8.4 %
Sunday		
Queen Anne	74.8 %	21.0 %
Wallingford	75.0 %	19.3 %
Kirkland	88.3 %	9.9 %

The trip mode analysis is again restricted to auto and walking insofar as those are the only modes that are factors in these neighborhoods. **Table 47** shows the variation in tip mode throughout the weekend. Walking percentages increased in all the study neighborhoods on Sunday.

Hourly Distributions

This analysis investigated when residents travel during the day. **Figure 16** shows the hourly distribution for Saturday and Sunday. Typically, people travel later on Sundays than Saturdays. This is apparent in the differing -peak locations in the distribution table.

Other Weekend Research

Two studies discussed in the literature search explored weekend travel in suburban areas. **Table 48** reflects Murakami's (1996) finding of average weekend trip length of 7.9 miles for suburban areas throughout the country. The three mixed use neighborhoods have, to varying degrees, a shorter average trip length than Murakami reported. The second column of the table shows the weekday average trip length comparison between the mixed use neighborhoods and the PSRC study areas. It is interesting to note that the mixed use neighborhood trip lengths are very similar between weekends and weekdays, and the Murakami number closely resembles the average trip length for outer ring suburbs.

The second study (Hu 1996) cataloged travel behavior by day of week for suburban areas. The author detailed multitudes of variables and travel characteristics. **Table 49** shows a few select measures that can be compared to measures in this data set and to average weekday numbers from the PSRC data. Such a comparison shows that travel frequencies are similar regardless of household location while the average trip lengths clearly increase in more suburban areas. In addition, women tend to travel more often than men. These findings concur with the ratio between mixed use trip length and suburban trip seen in Murakami's comparison above.

Table 48. Murakami - Average Trip Length Comparison

	Weekend	Weekday
Murakami (suburban)	7.9	
North Seattle	- -	4.7
Inner	- -	6.1
Outer	- -	8.0
Queen Anne	3.9	4.0
Wallingford	4.0	3.8
Kirkland	5.1	4.9

Table 49. Hu - Weekend Travel Comparison

	Freq. by household income 40k+	Freq. by gender (male/female)	Ave. trip length for shopping (miles)
Hu (suburban)	approx. 4.8	approx. 2.9 / 2.9	5.9
N. Seattle*	approx. 5.0	4.7 / 5.3	5.1
Inner*	approx. 5.1	4.7 / 5.3	8.7
Outer*	approx. 5.0	4.5 / 5.3	12.3
Queen Anne	approx. 5.8	5.6 / 5.7	3.1
Wallingford	approx. 4.7	4.6 / 4.7	3.2
Kirkland	approx. 5.1	4.9 / 5.1	3.5

* = Weekday data

Walking Trips

Much has been written about the possibility of walking trips substituting. for auto trips in mixed-use neighborhoods. A number of studies reviewed in the literature search indicated that people will use their cars less in neighborhoods where goods and services are ‘nearby.

The mixed-use data for this study are more complete than for most because the database includes short walking trips. This section takes a specific look at these weekend walking trips. There were a total of 749 pedestrian trips in the data base completed by 293 individuals. See **Table 50** for the neighborhood distributions of these trips.

Age

The average age of people who undertook walking trips is shown in **Table 51.** It does not appear different from the average age of all the study respondents.

Table 50. Weekend Walk Trip Distribution

	Number of Walking Trips	Number of Individuals With Walking Trips
Queen Anne	384	113
Wallingford	365	118
Kirkland	156	62

Table 51. Average Age of People Who Walk on Weekends

	Average Age (Years)
People Who Walk	
Queen Anne	42.5
Wallingford	37.4
Kirkland	49.3
All Participants	
Queen Anne	41.6
Wallingford	39.6
Kirkland	48.7

Household Type

An interesting finding is that people who walk appear to come from larger households on average than that of the respondents as a whole. There are more adults and children in households with walking trips **(Table 52).**

Tables 53 and 54 list the walking rates by day of week for various household types. The first set of rates includes only households with walking trips, while the second set of numbers displays the average walking rates based on all households. Individual numbers for "Households with waiking trips" are not included because the number count of households is low (between 2 and 25).

Table 52. Household Characteristics of People Who Walk on Weekends

	Household Size	Number of Adults per Household	Number of Children per Household
People who Walk			
Queen Anne	2.50	1.94	.52
Wallingford	2.47	2.07	.43
Kirkland	2.02	1.81	.21
All Participants			
Queen Anne	2.16	1.69	.47
Wallingford	2.15	1.81	.34
Kirkland	2.04	1.72	.32

Two-adult households without children walk most often. Interestingly, households with children do not walk less than other types of households. There does not appear to be a large difference between Saturday and Sunday walking rates within the three neighborhoods.

Table 53. Average Daily Walking Trip Per Household by Household Type (Saturday)

	Household Type				Total (walking trips per household)
	With Child(ren)	1 Adult (no children)	2 Adults (no children)	Seniors	
Households with Walking Trips					
Queen Anne					3.67
Wallingford					3.40
Kirkland					2.67
All Households					
Queen Anne	2.23	1.46	2.28	*.55*	1.79
Wallingford	1.59	1.63	1.81	*1.17*	1.75
Kirkland	*.76*	.25	.86	*1.05*	0.71

Italics = (n) households less than 25

Table 54. Average Daily Walking Trip Per Household by Household Type (Sunday)

	Household Type				Total
	With Child(ren)	1 Adult (no children)	2 Adults (no children)	Seniors	(walking trip per hh)
Households with Walking Trips					
Queen Anne					3.94
Wallingford					3.05
Kirkland					2.81
All Households					[redacted]
Queen Anne	1.80	1.59	2.20	*2.00*	
Wallingford	2.00	1.27	1.49	*0.71*	
Kirkland	*0.19*	*1.00*	0.73	.80	

Italics = (n) households less than 25

Number of vehicles

An interesting finding **(Table 55)** is that people who walked tended to have similar or slightly more vehicles than other survey respondents.

Annual Income

Table 56 shows walking rates by annual income for the three neighborhoods. Lower income residents walk more often than those in higher income households. Queen Anne residents walk most often, while as shown earlier, Kirkland's walking rates are lower than those in the other two neighborhoods.

Table 55. Average Number of Vehicles of Those Who Walk

	Average Number of Vehicles
People Who Walk	
Queen Anne	1.96
Wallingford	1.64
Kirkland	1.65
All Participants	
Queen Anne	1.74
Wallingford	1.62
Kirkland	1.89

Table 56. Average Daily Walking Rates by Annual Income

	Annual Household Income	
	Less than $ 35,000 a year	More than $35,000 a year
Number of trips per person per day		
Queen Anne	1.43	0.89
Wallingford	0.82	0.77
Kirkland	0.51	0.43
Number of trips per household per day		
Queen Anne	1.88	1.71
Wallingford	1.24	1.53
Kirkland	0.73	0.71

Trip Length

Figure 17 illustrates the trip length histogram for walking trips. Seventy-three percent of trips were less than one-half mile, and 40 percent of the trips were less than one-quarter mile. Very few people will undertake walking trips of more than one mile.

CONCLUSION

The large body of literature reviewed for this paper generally supports the notion that mixed-use or neotraditional neighborhoods can reduce the amount of travel for most households, as measured by the number of miles traveled. The research underlying this paper generally found support for these notions, although we concur with others that the linkage is very complex. Residents of the two mixed-use neighborhoods in Seattle traveled 27 percent fewer miles than the remainder of North Seattle, 72 percent fewer than the inner suburbs and 119 percent fewer than the outer suburbs. If one of these mixed-use neighborhood were somehow relocated to the outer suburbs would it travel characteristics remain the same? It's doubtful, but indications from this research based on looking at various breakdowns of trip and household types make it clear that substantial reductions in travel distances can be accomplished with appropriate urban design.

The paper also looked at weekend travel for the mixed-use neighborhoods. This analysis showed that travel miles on Saturday were about 25 percent greater than Sunday, and Saturday travel was 12 percent greater than the average weekday. Distance per trip for weekend travel was essentially the same as weekday. Comparison of the mixed-use neighborhood weekend data to NTPS weekend travel for suburban sites showed a similar ratio of travel distances as found for comparisons of weekday travel in mixed-use sites and

King County suburbs. There is some evidence that mixed land uses has the same effect on weekend trips as weekday trips.

This paper also gives credence to the few researchers who have looked at travel time rather than distance as a principal measure. The large differences among the areas reported for travel distance are not seen when considering travel time. The travel time was about 90 minutes per person regardless of where that person lived. Variation by age and family life cycle stage was also remarkably small. This "travel time budget" of about 90 minutes is an interesting finding and compares favorably to previously cited studies.

This research has several implications for travel demand modeling. First, in order to model new (old) neighborhood forms, short trips must be handled much better than in the past. The sheer number of short trips and the fact that they are substituting for longer trips that would be made in more modern suburbs dictates they be modeled more faithfully. Transportation zone boundaries swallow entire neighborhoods, making consideration of pedestrian and many bicycle trips very difficult. Second, if travel time budgets are as uniform as found in this work and shown in others, perhaps they could be used more in the calibration and validation process to assure that models operate within time constraints by various parameters. Third, the travel time budget issues and close ties between land use and short trips reinforce the notion that feedback loops are an increasingly important part of the travel forecasting process.

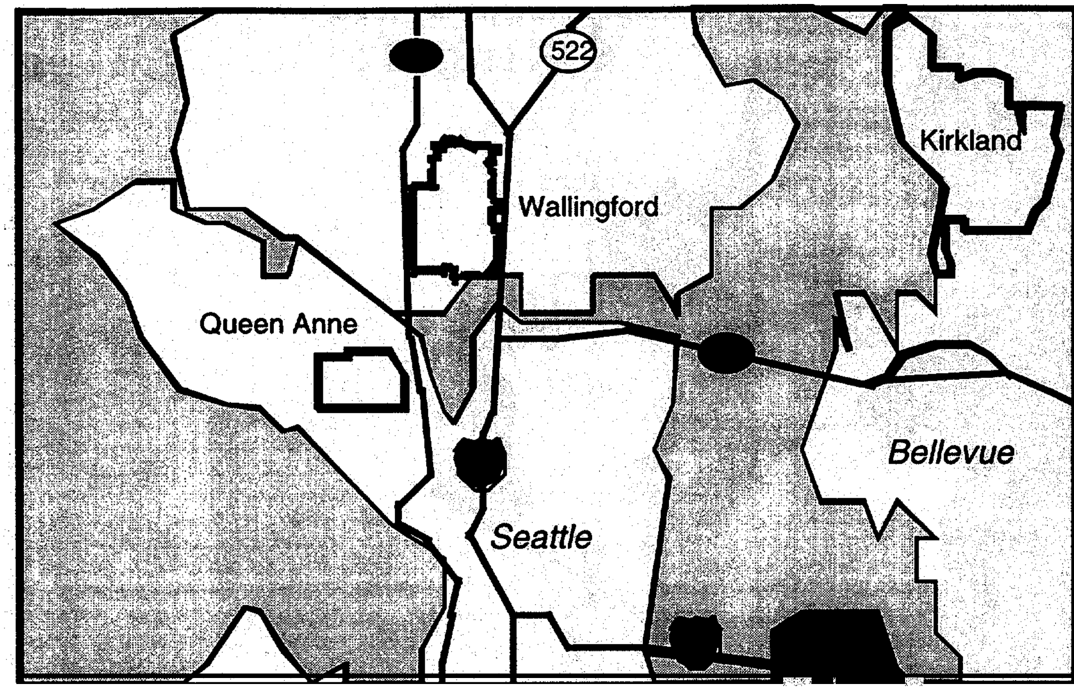


Figure 1. Study Area Vicinity Map

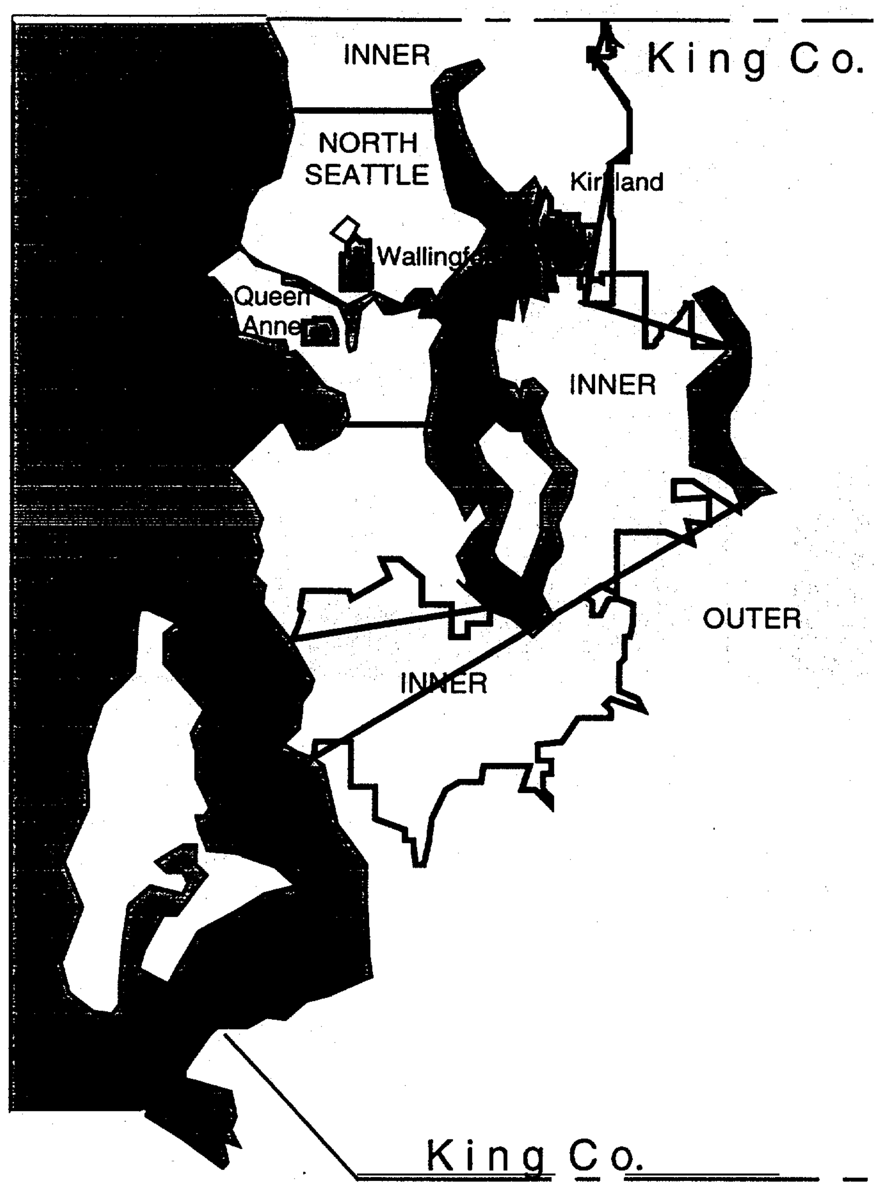


Figure 2. Analysis Zones

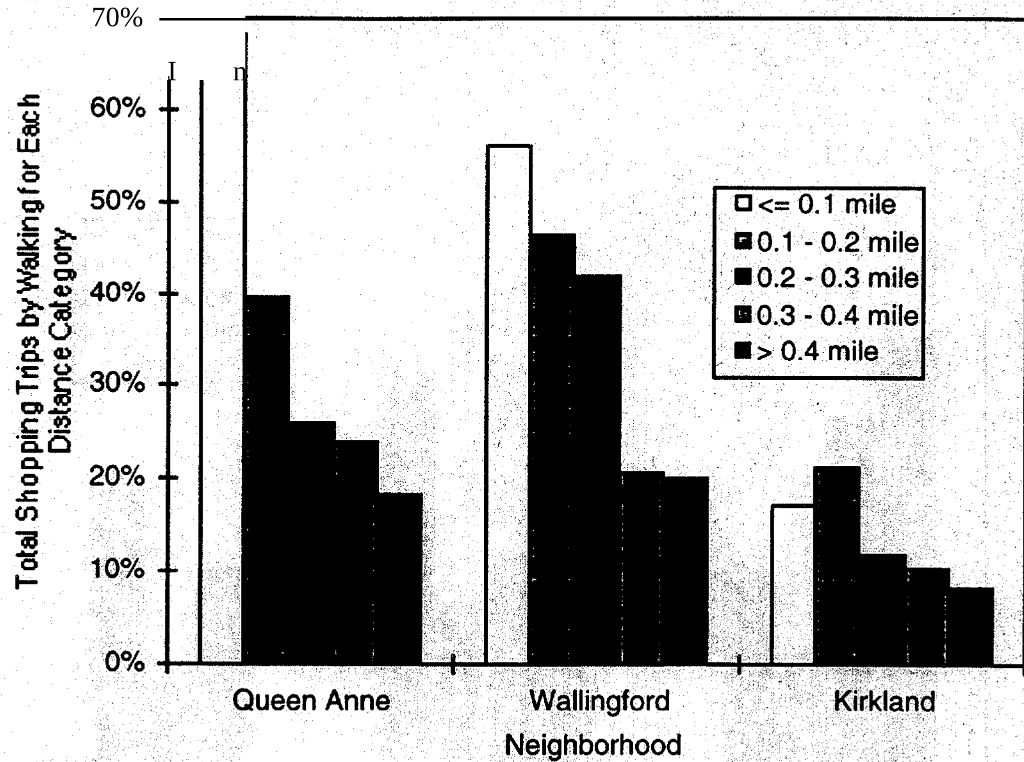


Figure 3 Total Shopping Trips by Walking Related to Household Distance from Commercial Streets

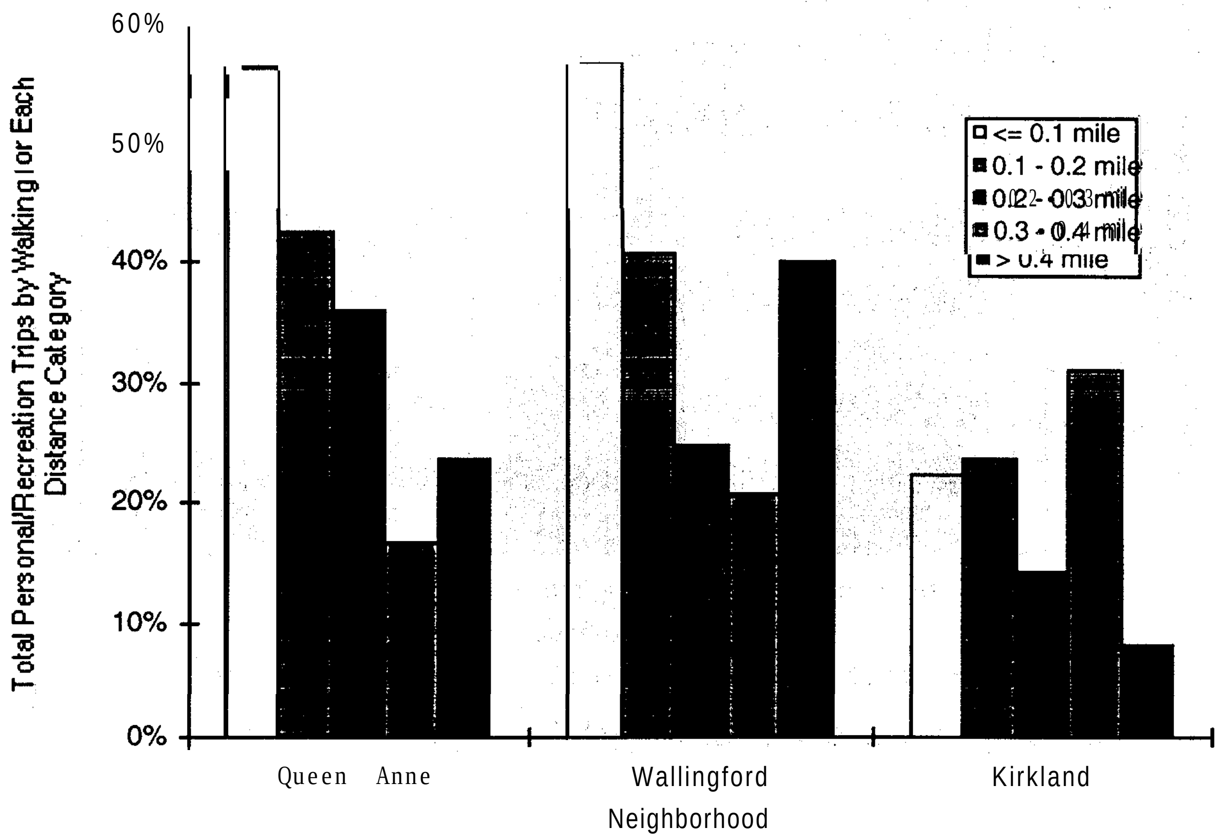
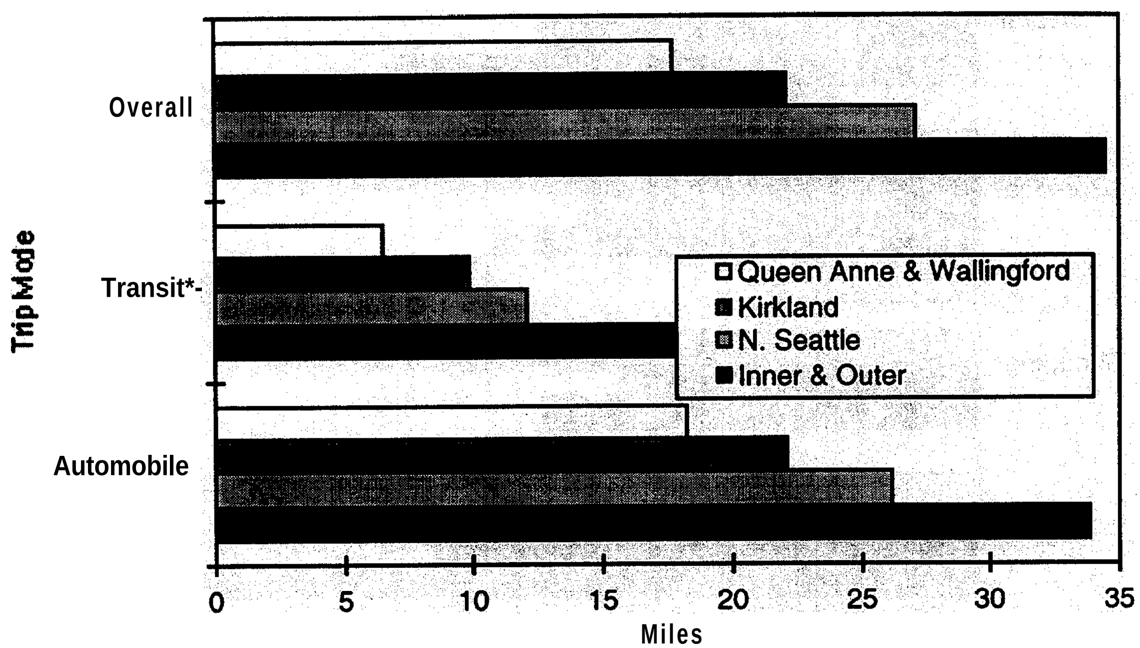


Figure 4. Total Personal/Recreation Trips by Walking Related to Household Distance from Commercial Streets



* Total mileage, for all modes, where a household member used transit

Figure 5. Average Total Daily Mileage by Mode (Weekdays)

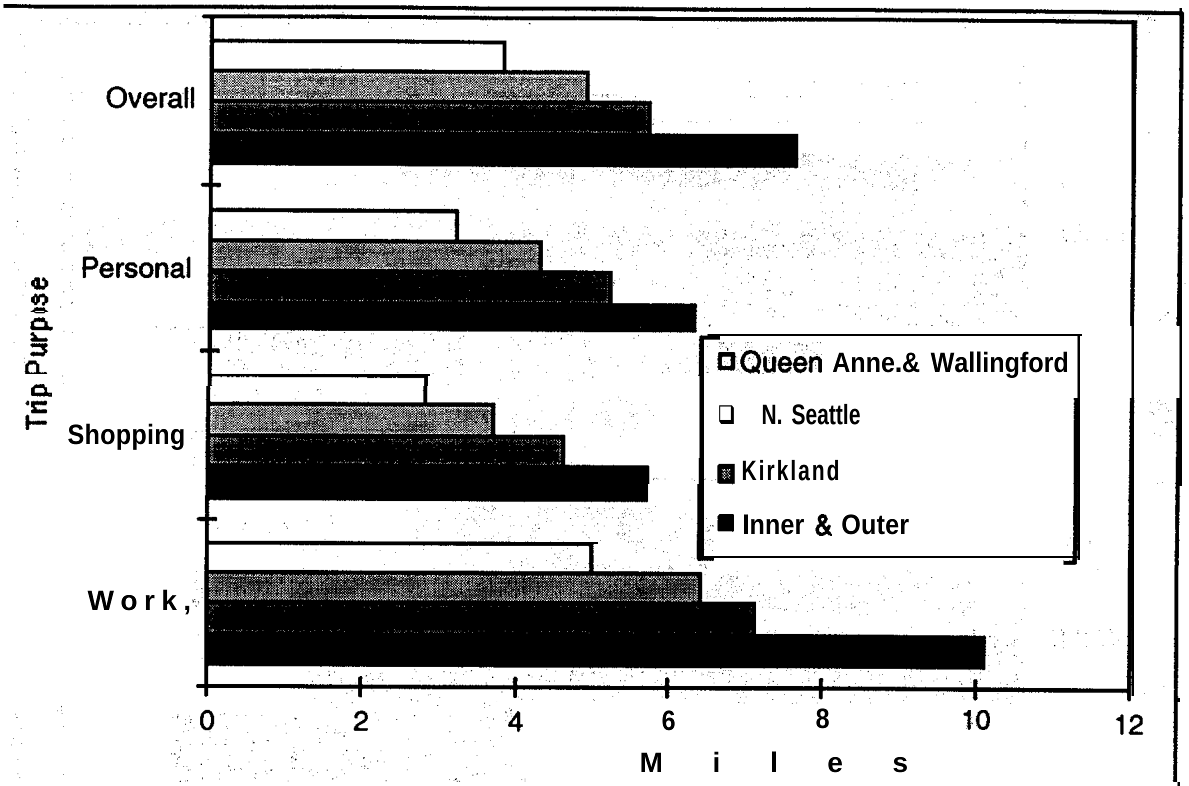


Figure 6. Average Trip Mileage per Person by Purpose (Weekdays)

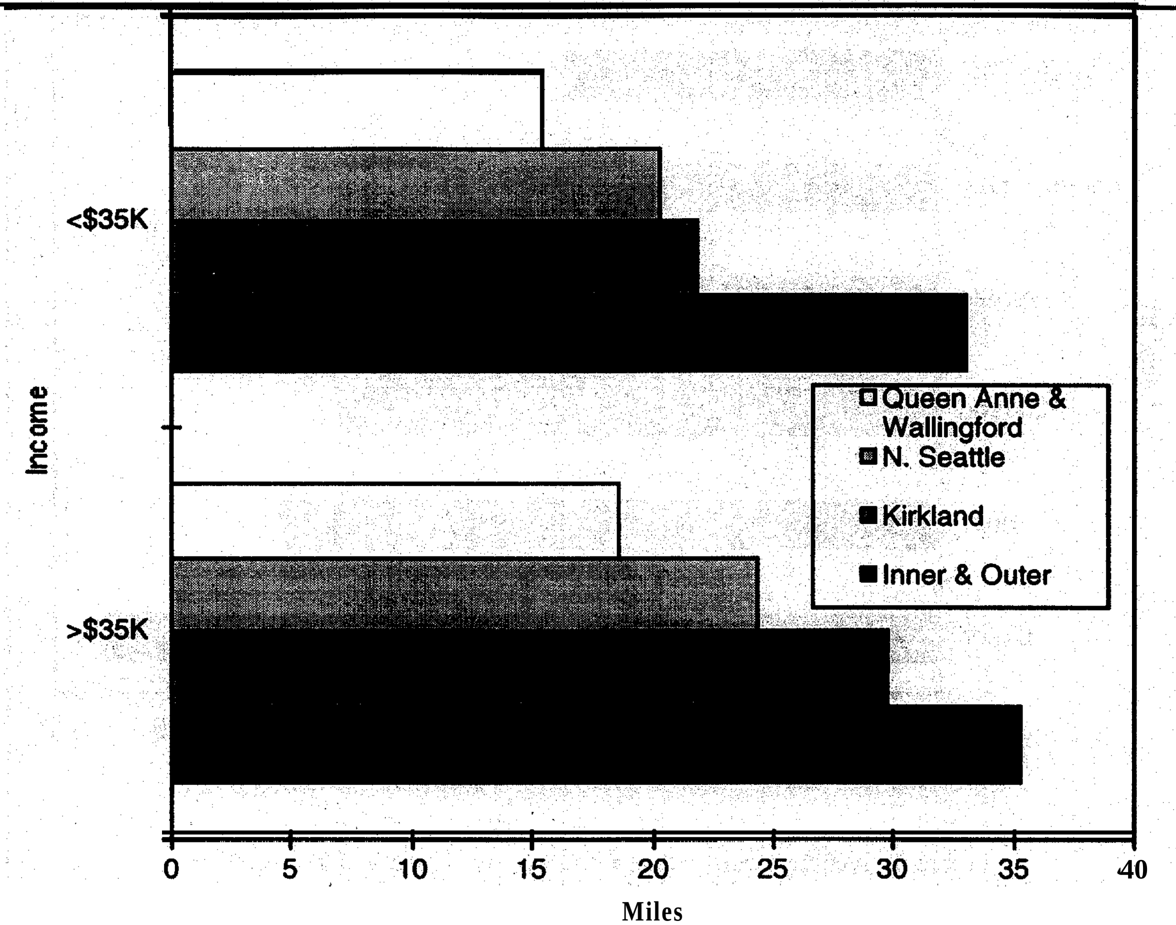


Figure 7. Average Daily Person Mileage for Household by Locatidn and Income (Weekdays)

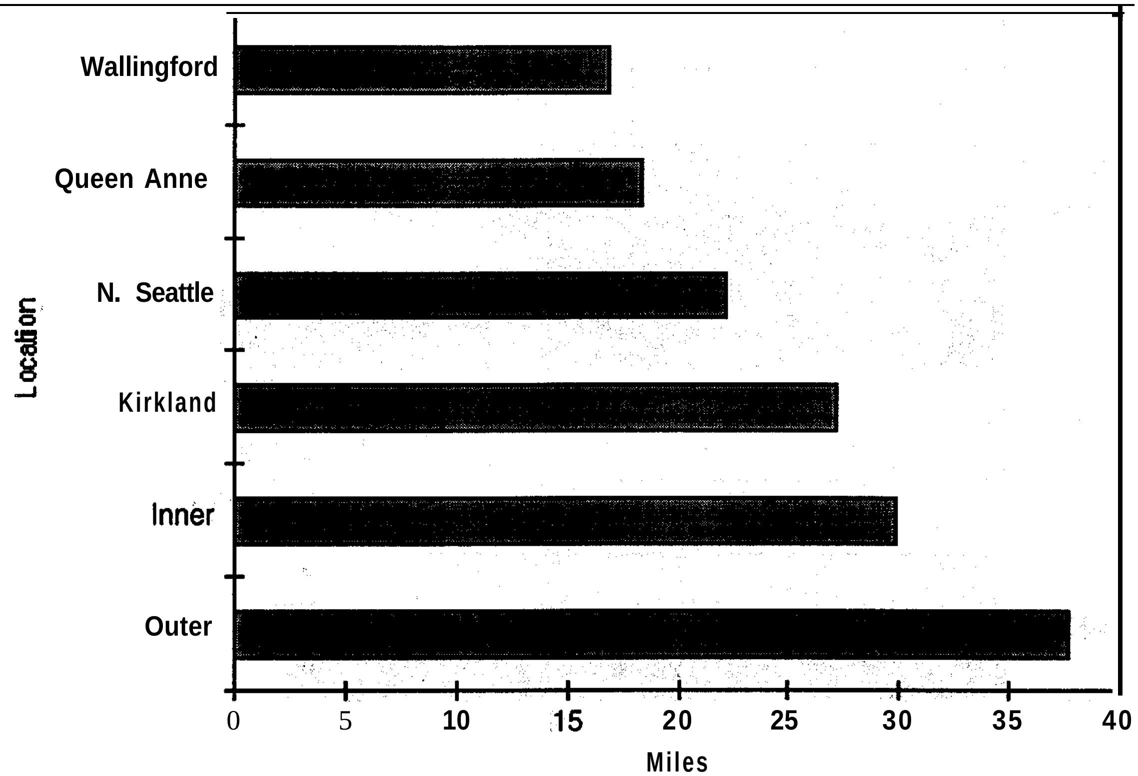


Figure 8. Average Daily Person Mileage by Household Location (Weekdays)

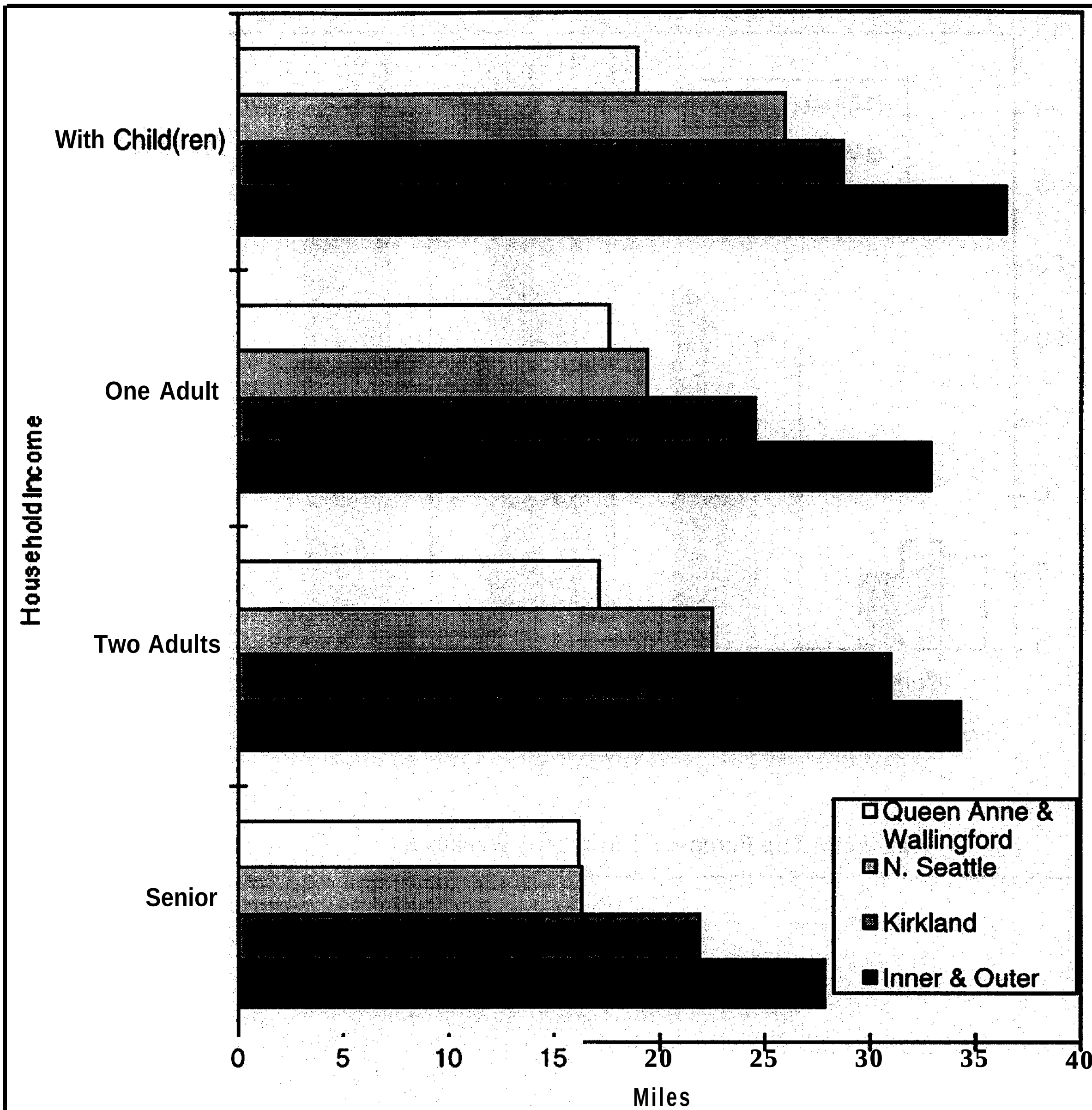


Figure 9. Average Daily Person Mileage by Household Type (Weekdays)

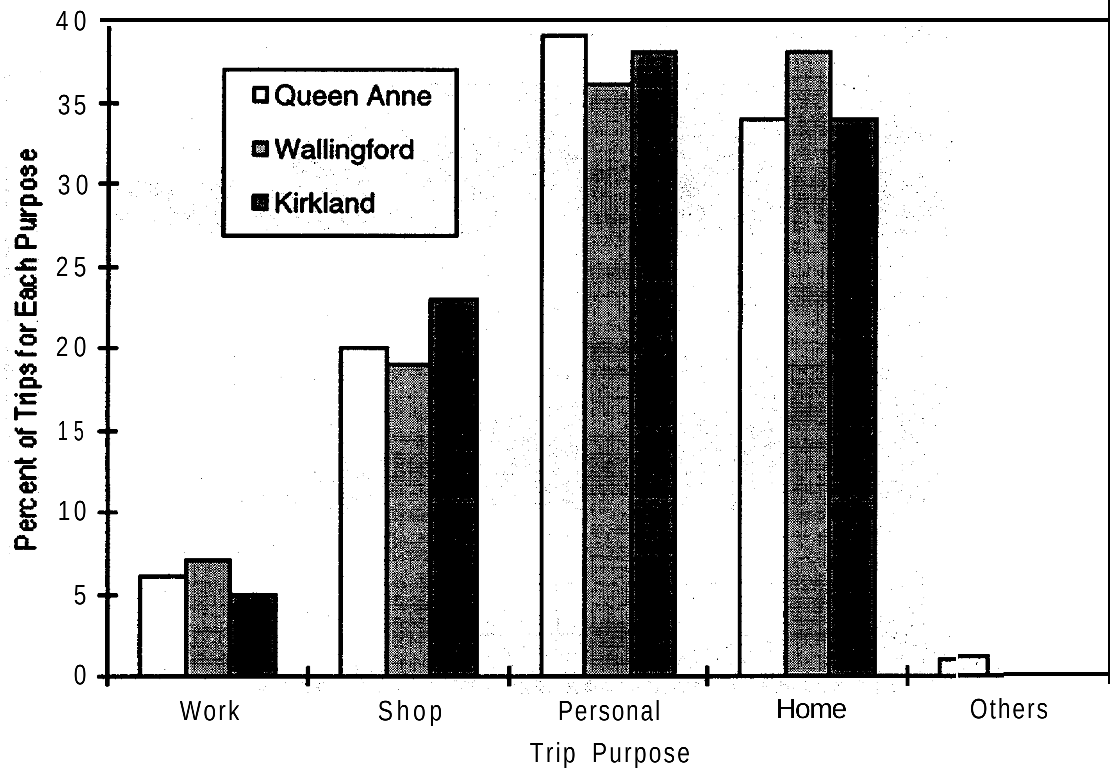


Figure 10. Trip Purpose Distribution (Weekends)

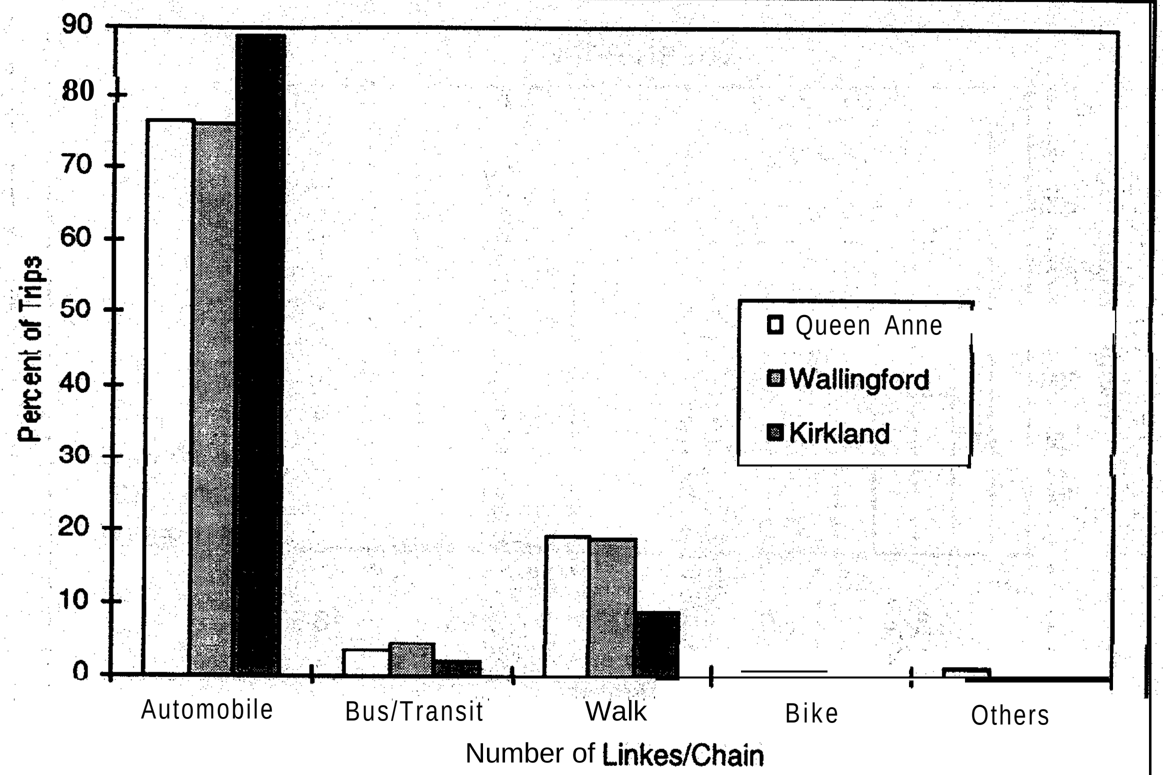


Figure 11. Trip Mode Distribution (Weekends)

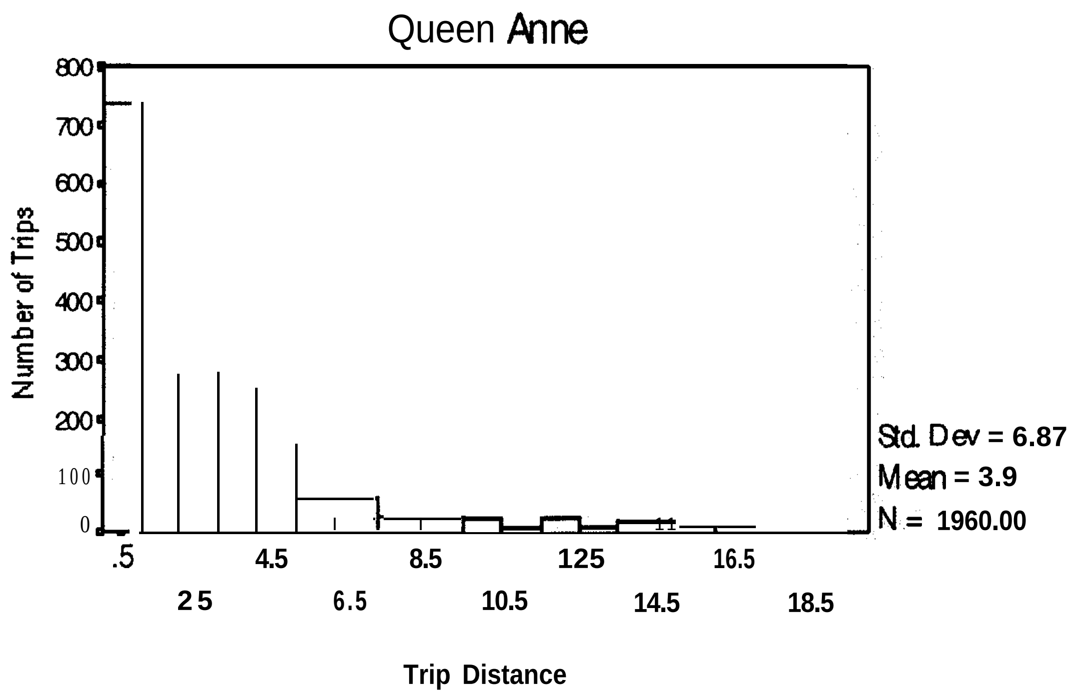


Figure 12. Trip Length Histogram - Queen Anne (Weekends)

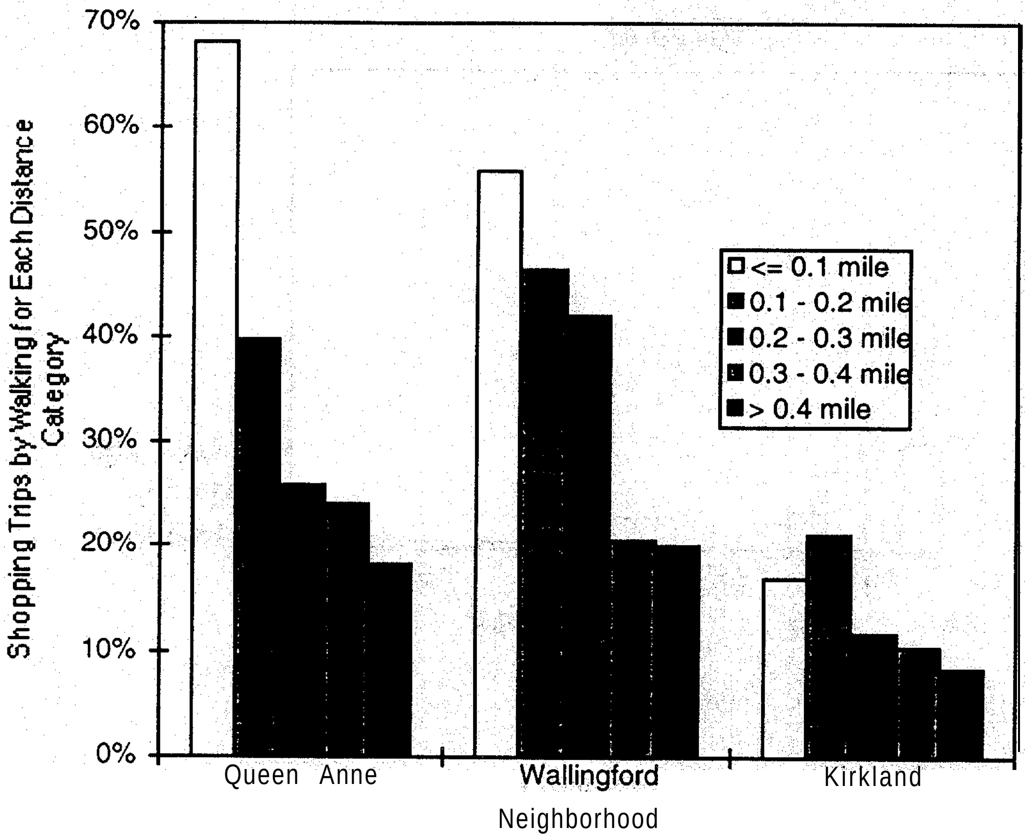


Figure 13. Shopping Trips by Walking Related to Household Distance from Commercial Streets

Figure 13. Trip Length Histogram - Wallingford

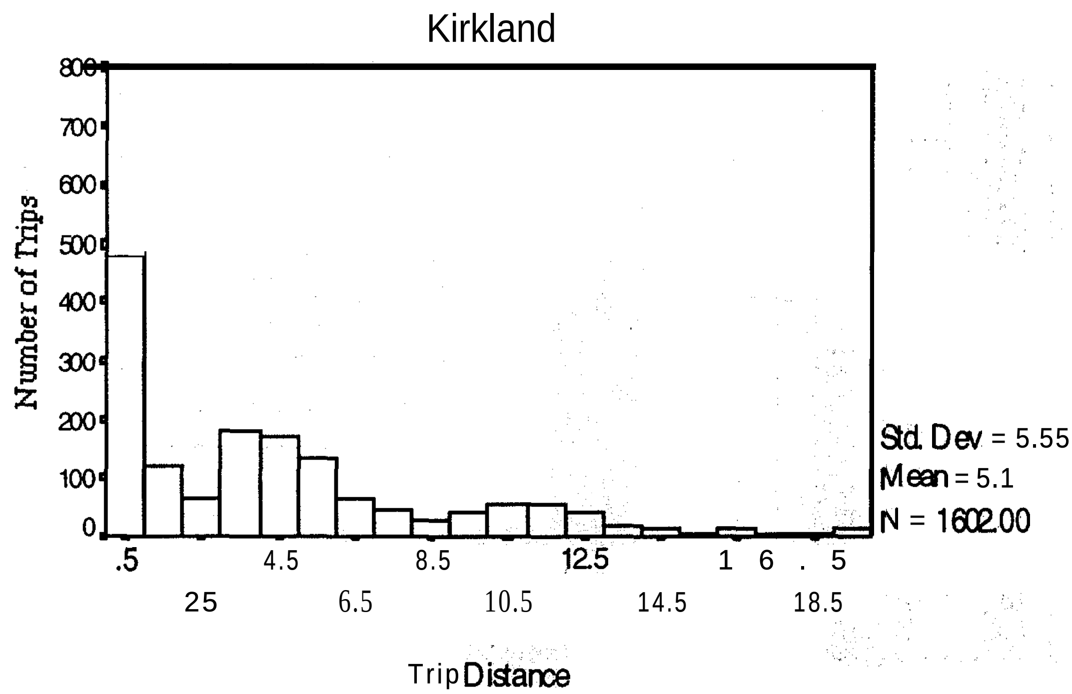


Figure 14. Trip Length Histogram - Kirkland (Weekends)

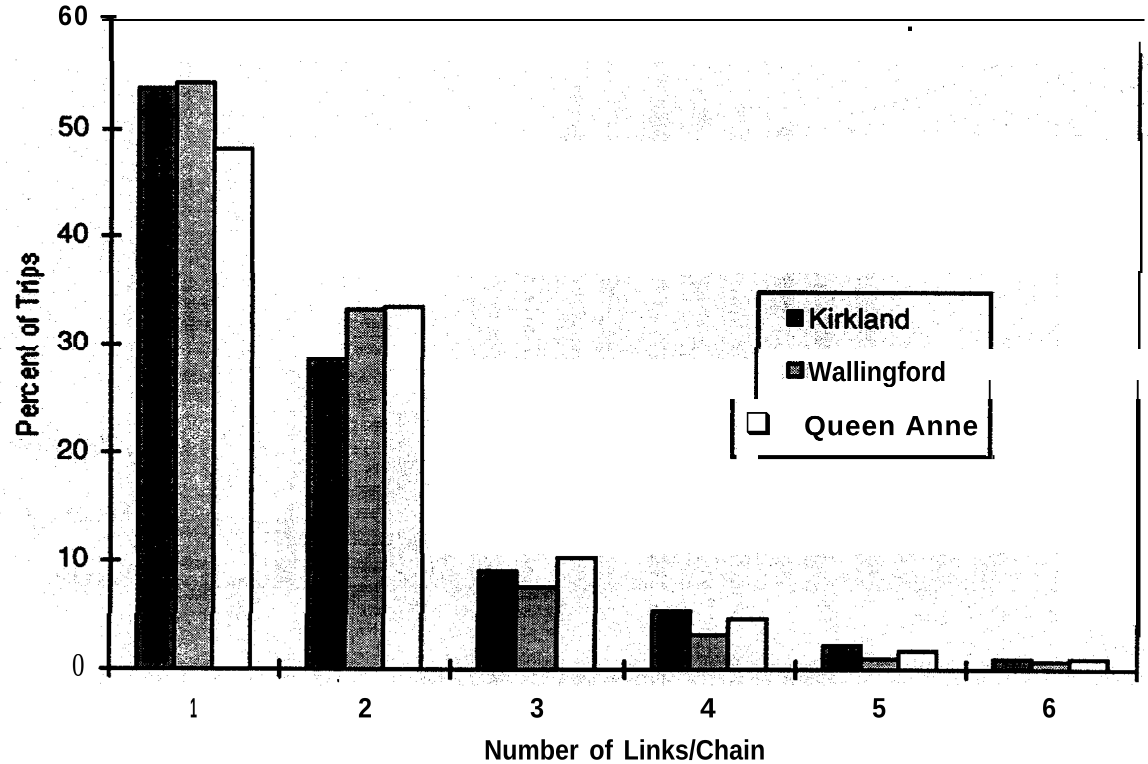


Figure 15. Links per Chain Distribution (Weekends)

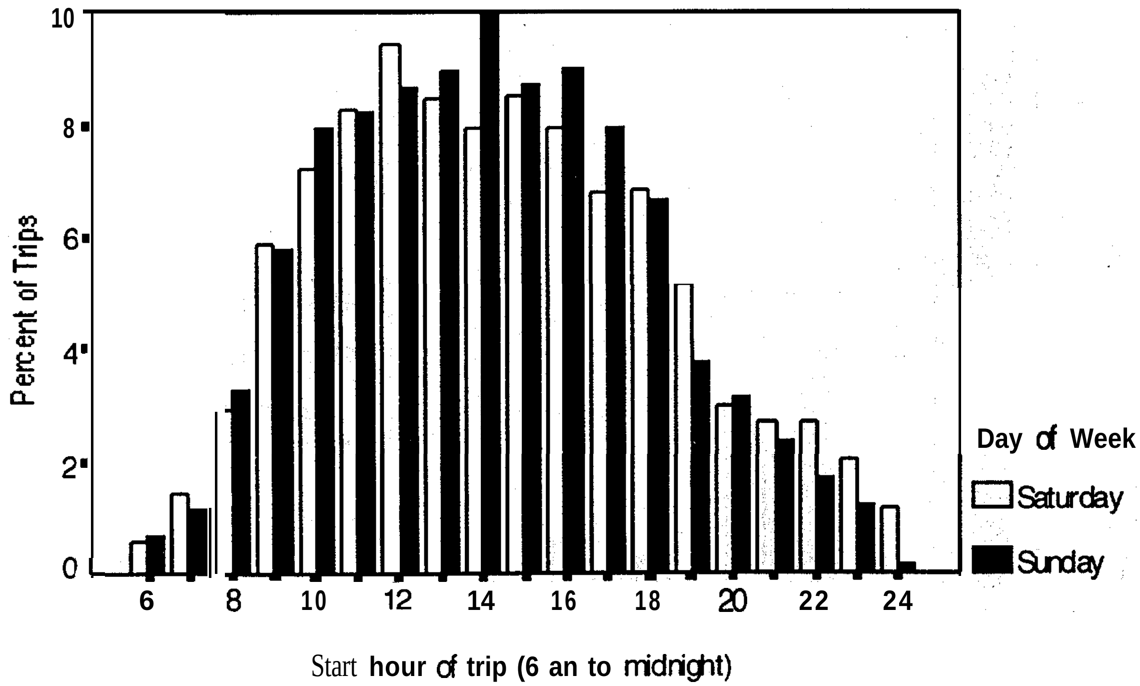


Figure 16. Hourly Distribution by Time of Day

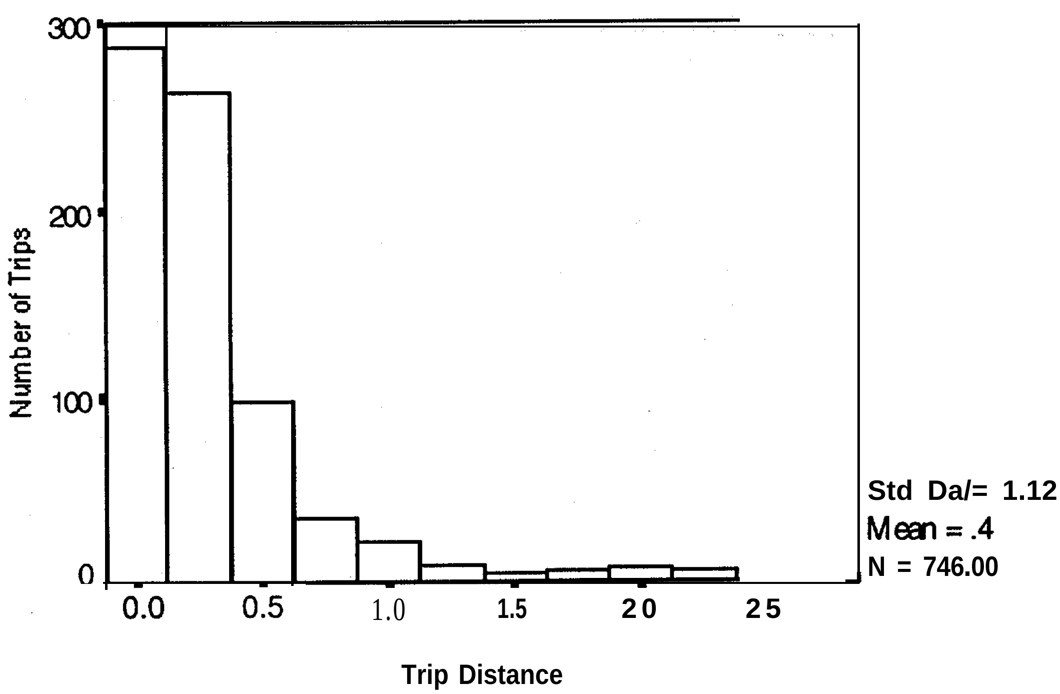


Figure 17. Trip Length Histogram for Walk Trips (weekends)

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INCORPORATING URBAN DESIGN VARIABLES IN METROPOLITAN PLANNING ORGANIZATIONS' TRAVEL DEMAND MODELS

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Metropolitan Planning Organizations (MPOs) find it difficult to address urban design issues in their work programs for both technical and policy reasons. Even though many MPOs have endorsed general land use policies to keep development from flood plains, protect open space and support transit oriented development, only a few MPOs have any real input into local land use and zoning decisions that affect urban design. The responsibility for zoning most often rests with municipal or other local officials. While these local officials may be members of or represented on MPO policy boards, their zoning and land use decisions. are primarily driven by real estate market forces, constituents' interests, intergovernmental rivalries and funding availability[1].

Few MPOs have challenged this division of planning responsibilities. Metropolitan Planning Organizations have historically carried out regional transportation planning at a scale too gross to consider how the design' of planned urban developments, residential subdivisions and office parks affects travel demand. In the socioeconomic and land use data files that MPOs use for transportation planning, these developments appear only as added employment, housing or population summarized within some geographic unit.

In northeastern Illinois, for example, the quarter square mile quarter-section is the principal geographic unit for assembling land use, population and employment transportation planning data. Within quarter-sections, activities can be separated by as much as a mile of right angle distance. Even though a quarter-section may have both retail employment and households, there is no way to determine whether stores and households are distributed throughout the quarter-section and located close to one another, or clustered in opposite corners of the quarter-section and separated by up to a mile of walking or driving distance.

The geographic level at which MPOs apply the travel demand models for regional planning and major investment studies is often even. larger than the geographic level at which the socioeconomic and land use data are maintained. The number of analysis zones that can be used in travel demand models is more constrained by computing requirements than the number of geographic units in the land use and socioeconomic databases. Again considering northeastern Illinois as an example, the 16,300 plus quarter-sections that are used to maintain the primary transportation planning data are further aggregated to 1,900 to 2,000 analysis zones for regional trip distribution, mode choice and assignment. Most analysis zones are one square mile sections, but they increase to four square mile zones in suburban counties, where much of the new development is taking place.

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1 Robert T. Dunphy. "Transportation Oriented Development: Making a Difference." *Urban L-and,* July, 1995.

Forecasting urban design variables is extremely problematic for MPOs. Should these variables be part of the endorsed regional land use and socioeconomic forecast used for, transportation planning or remain "wild card" variables that can be manipulated by modelers within the framework of a more general forecast? Should the values for future urban design variables be set through policy decisions, be the result of a technical forecasting process, extrapolated from existing values, or be allowed to range between reasonable maximum and minimum values for scenario testing?

Even if there were no technical problems in forecasting urban design variables, it would still be difficult for many MPOs to explicitly include these variables in their endorsed forecasts. Agreement on gross population and employment figures is easier to achieve than agreement on land use densities, land use 'mixes,' multiple unit housing and similar variables that are more controversial. Local officials are also unlikely to willingly give up any of their prerogatives over zoning.

Reasons to Consider Urban Design Variables

There are emerging arguments for MPOs staff to take the relationship between urban design and travel demand more seriously. 'The air quality conformity requirements that MPOs face provide an incentive to include urban design variables. Those regions in non-attainment areas, and especially those regions classified as moderate and above ozone non-attainment areas, must find ways to reduce, the growth in vehicle-miles of travel. Urban design is seen as one means to reduce personal automobile use, by locating activities so that nonmotorized and transit trips can be substituted for automobile trips.

In the northeastern Illinois region, and in many other regions, a loose confederation of public interest organizations are active in the MPO's planning and project programming processes. These groups focus on. improving the quality of life, reducing reliance on the automobile for personal travel, and promoting transit and pedestrian/bicycle usage. It is simply impossible for MPOs to ignore these groups' interests, which all touch on urban design, due to their important role in the MPO planning process.

Transit interests have also keyed on the relationship between urban design and transit ridership because transit ridership depends on the types and densities of activities in the immediate vicinity of stations and bus stops. Transit proponents have also reversed the development (cause) and ridership (effect) relationship to argue that the availability of transit can influence location decisions, creating an urban environment that supports transit ridership. Both arguments undermine the certainty of transit ridership forecasts based upon a single forecast compiled in analysis zones larger than convenient transit access walking distances.

The technology associated with the maintenance, display and manipulation of demographic and land use data is rapidly changing within MPOs. This technology includes not only the Geographical Information Systems (GIS) software, but also government and private vendor databases for GIS applications, more efficient land use and demographic data collection, and data resources available through the Internet. This technology allows MPOs to maintain land use and socioeconomic data at much less aggregate geography than previously. A wide range of urban design variables - mix of housing types, running feet of sidewalk, distances between households and retailing, the number of households within an eighth of a mile of a bus stop - can be readily developed and then used as independent variables in travel demand models. Just as importantly, this technology can generate urban design variables - vacant or underutilized housing, distributions of population characteristics for households within transit comutersheds, land available for development - for use as independent variables in land use and demographic forecasting processes, as well as for the creation of alternative development scenarios.

Modeling Travel Demand Impacts of Urban Design

Those who argue that the travel demand models need to be responsive to urban design variables expect urban design to influence travel behavior in the following manner.

1. **Increase transit ridership by reducing the access/egress distances for transit.** This mode shift is achieved by increasing the densities around transit stations and bus stops, more efficient location of transit services relative to activities, and improving the pedestrian environment around stations and stops.

2. **Substitute nonmotorized trips for vehicle trips.** Urban design can increase nonmotorized travel by mixing activities so that trip productions'and attractions are located within walking distances of one another. This means that some retail and service activities are located within reasonable walking or biking distances of residences. Another way to improve the pedestrian and bicycle environment is to make it easier to complete pedestrian and bicycle trips either by eliminating barriers to nonmotorized travel or by improving pedestrian and bicycle facilities.

3. **Shorten trip lengths.** It is argued that exclusionary zoning and market forces have tended to segregate activities and lengthen trips. Workers must live some distance from their place of employment because adequate or affordable housing is not available near their job sites. Shoppers have to travel to regional shopping centers for even the most ordinary purchases and services. Better urban design would locate activities linked as trip productions and attractions as closely together as possible.

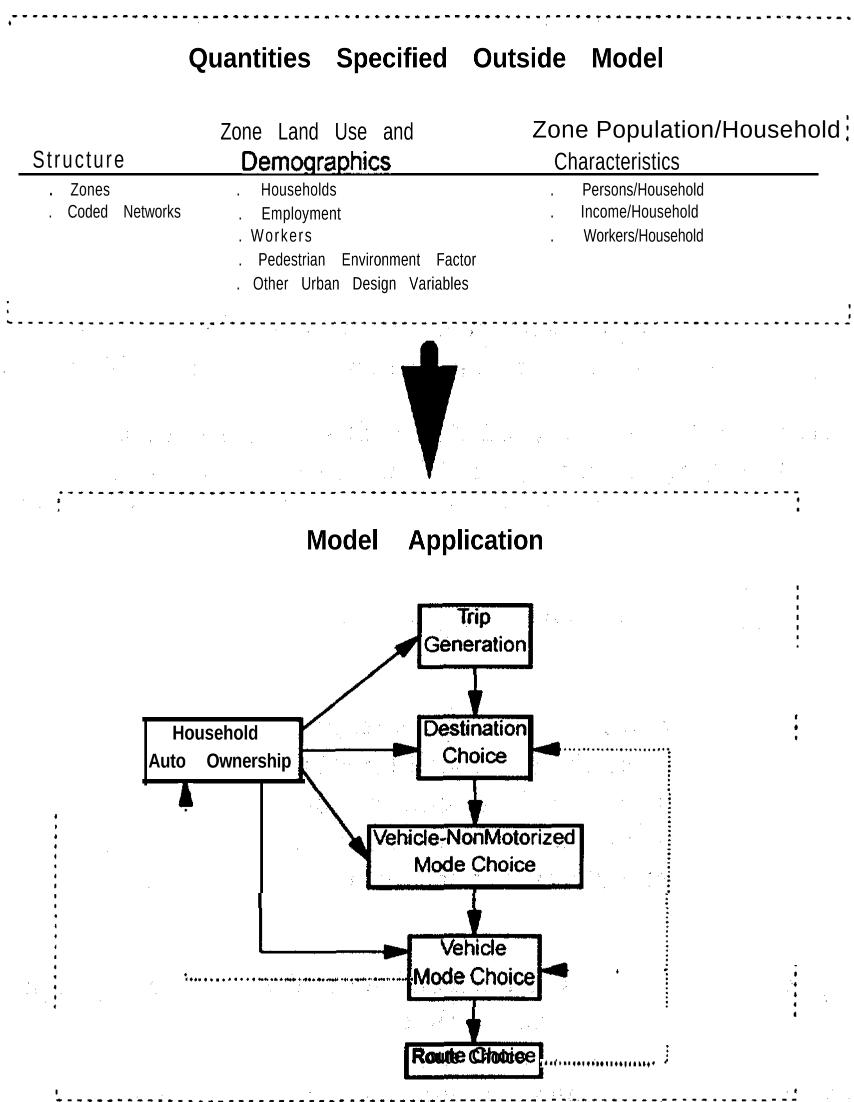
4. **Increase transit ridership by altering travel patterns.** In order to have enough transit ridership to support a major transit investment, enough riders and suitable destinations for them have to be located in the corridor served by the line. A mix of residential and employment at adequate densities must be located in a transit corridor to create travel patterns that can be well served by the corridor's transit service.

5. **Alter trip generation.** There is a general sense that urban design can affect the character of household travel. Household trip generation models that incorporate auto ownership usually indicate that vehicle. trips are lower when auto ownership is less, although auto ownership is often a surrogate for household income. When total household trip generation is considered, including walk and bicycle trips, these relationships are much weaker. If more

shopping is located in residential areas will households substitute more frequent short home to shop trips for longer weekly trips to a shopping center? Are transit commuters more likely to take care of errands during the lunch hour than auto commuters, who carry our the same errands while traveling to and from work?

Figure 1 is a diagram showing the sequence of person travel demand models in the modeling process under development at CATS. For simplicity, some details that affect the application of the models, such as trip purpose and time of day, are omitted. The Figure 1 process is typical of the modeling approaches that several larger MPOs have in place or under development. The purpose of this diagram is to help identify where the travel demand impacts from urban design variables can be modeled.

Figure 1. State-of-the-Art Travel Demand Modeling Process



Quantities that are specified prior to the application of the models are listed in the top of Figure 1 under the headings model structure, zone level land use and demographic quantities, and zone level population/household characteristics. The sequence of model steps is shown beneath. It a slightly expanded version of the traditional four step modeling process. Trip generation includes both vehicle and nonmotorized trips. Destination choice is a more generic term for trip distribution, and it also includesnonmotorized as well as vehicle trips. An initial mode choice step allocates trips to vehicle and nonmotorized modes. The remaining vehicle trips are split into vehicle modes in the subsequent vehicle mode choice model. Route choice refers to the assignment of trips onto the coded networks. A household auto ownership model estimates levels of household auto ownership, which is an independent variable in trip generation, destination and mode choice. Feedback loops in the diagram are used to enter the auto dependency associated with a household's location into the household auto ownership model, and to feedback the increased travel times and costs associated with highway congestion.

Table 1 combines the anticipated impacts upon travel behavior from urban design with the Figure 1 travel demand models to show where these impacts are likely to be reproduced. The rightmost column lists alternative means of incorporating urban design impacts in the models, based on a brief review of the literature and the.author's experience in peer, group reviews of agency travel models. The' next sections of this paper follow the organization of Table 1.

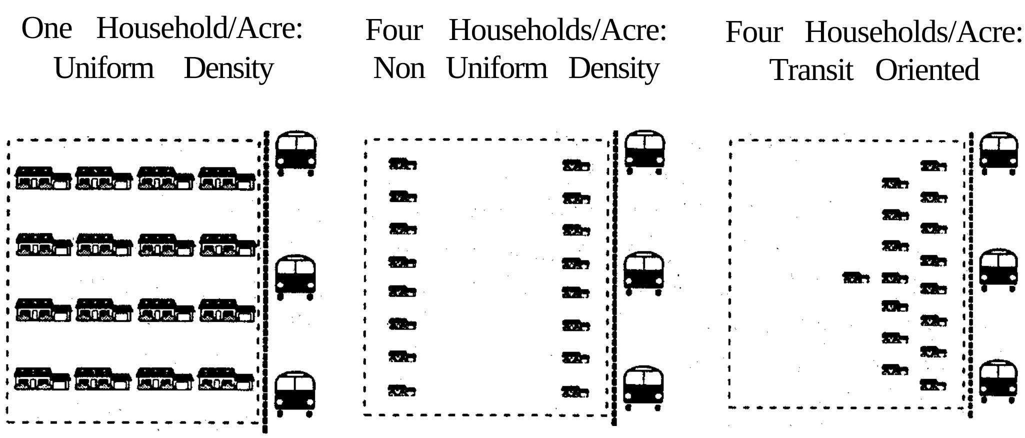
Table 1. Linkages Between Urban Design and Travel Demand Models

Impacts from Urban Design	Models Affected	Means of Representation
Transit Access/Egress Distances	1. Vehicle Mode Choice 2. Vehicle-Nonmotorized Mode Choice	1. Reduced Zone Sizes in Transit Service Areas 2. Network Coding and Locations of Zone Centroids 3. Market Segmentation of Households/Population and Employment by Distance from Transit 4. Pedestrian Environment Factor
Nonmotorized Travel	1. Vehicle-Nonmotorized Mode Choice 2. Trip Generation 3. Auto Ownership	1. Include Nonmotorized Trips in Trip Generation 2. Pedestrian Environment Factor 3. Other Urban Design Variables
Trip Lengths and Travel Patterns	1. Destination Choice	1. Use Generalized Cost Logsum That Reflects Nonmotorized and Transit Zone to Zone Costs 2. Representation of Transit Access/Egress Impedances
Trip Generation	1. Trip Generation 2. Auto Ownership	1. Pedestrian Environment Factor 2. Other Urban Design Variables

Representation of Transit Access/Egress in Mode Choice

To understand the importance of the access/egress component of transit utility, one only has to realize that over estimating the distance from home to transit service by a half mile increases the transit trip time by an additional ten minutes of out-of-vehicle walking time, which is generally valued more than in-vehicle time. Figure 2 illustrates why the average zone transit access/egress characteristics used in the travel demand models are often insensitive to alternative urban designs.

Figure 2.' Transit Access Distance and Local Laud Use Organization



Households	640	640	640
Area/Household	One Acre	Quarter-Acre	Quarter-Acre
Average Transit Access Distance	0.63 miles	0.63 miles	0.24 miles
Households < 0.5 Miles From Transit	220	320	640

This figure shows three different development patterns for 640 households in a one square mile zone. Bus service is available along the east side of the zone at three stops spaced one-half mile apart. The first development alternative features a perfectly uniform density of households on one acre parcels.' The second alternative increases the density of households to four per acre and locates them on the east and west sides of the zone, as if the households were oriented to north-south arterial streets bordering the zone. In the last land use development pattern, the density is again four households per acre, but the households are oriented to the east side of the zone where transit service is available.

Two measures of transit accessibility are listed' in the table beneath the three land development alternatives, the average distance from all the zone's households to transit service and the number of households within one-half mile of a bus stop. The three alternatives feature quite different transit accessibility. Every household in the transit oriented development pattern is within one-half mile of a bus stop, while the other development, scenarios have households located further than one-half mile from transit service. Average transit access distances for the two non-transit oriented scenarios are more than double that of the transit oriented scenario. The 0.41 mile difference between the uniform density and transit oriented average transit access distances equals roughly eight minutes of extra walking time.

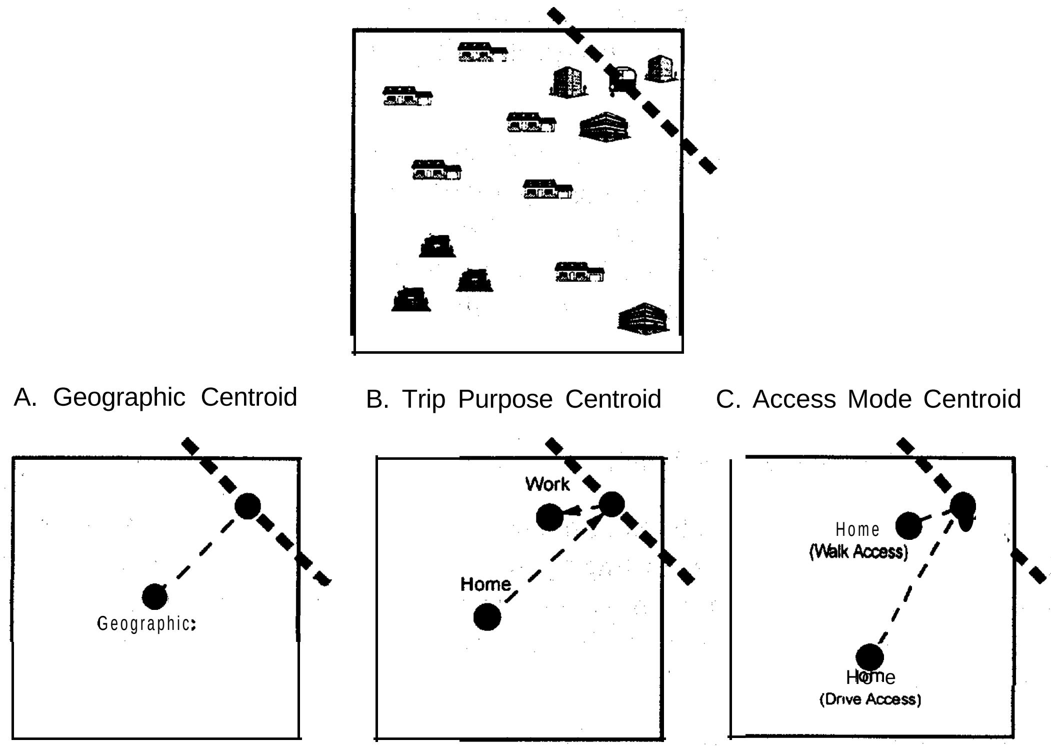
Urban design attributes can be introduced into transit access/egress utilities by changing the way transit access/egress characteristics are measured. Placing smaller zones around transit stations permits access/egress times and distances to be measured more accurately. Zones with reasonable walk to transit access can be distinguished from zones without walk access. Pro-transit urban design policies can then direct new development to walk access zones. Unfortunately, this approach rapidly increases the number of zones in any region with a reasonable amount of transit service. Reducing the zone sizes around rail transit and commuter rail stations in northeastern Illinois from one square mile to quarter-sections would add more than five hundred additional zones.

Transit access/egress quantities in mode choice models are frequently scaled directly from the coded transit network, Adjusting the location of zone centroids according to the trip purposes and choice structure in the mode choice; model allows more accurate estimation of transit access/egress. characteristics. Different rationales for locating zone centroids are illustrated in Figure 3.

The top diagram in this figure shows the distribution of activities in a zone served by a transit station in the upper right corner. A zone centroid and one or more access links are depicted in the lower three diagrams, which show different approaches for locating zone centroids within the zone. The simplest choice-is the geographic center of the zone. Centroid locations can also be weighted by different purpose trip ends, illustrated in the second example by a home centroid and a work centroid. Average distance from households to the station are likely to be different than the average distance from the station to employment. In

A similar approach can be used to locate centroids by transit access mode. In 'the last example, the walk. to station access link distance is measured using, centroid- coordinates that are weighted by all households within reason-able walking distance of the, transit station. The auto to station access link distance is based on centroid coordinates weighted by the remaining households in the zone, that are located beyond comfortable walking distance from the station.

Figure 3. Urban Design and Zone Centroid Location



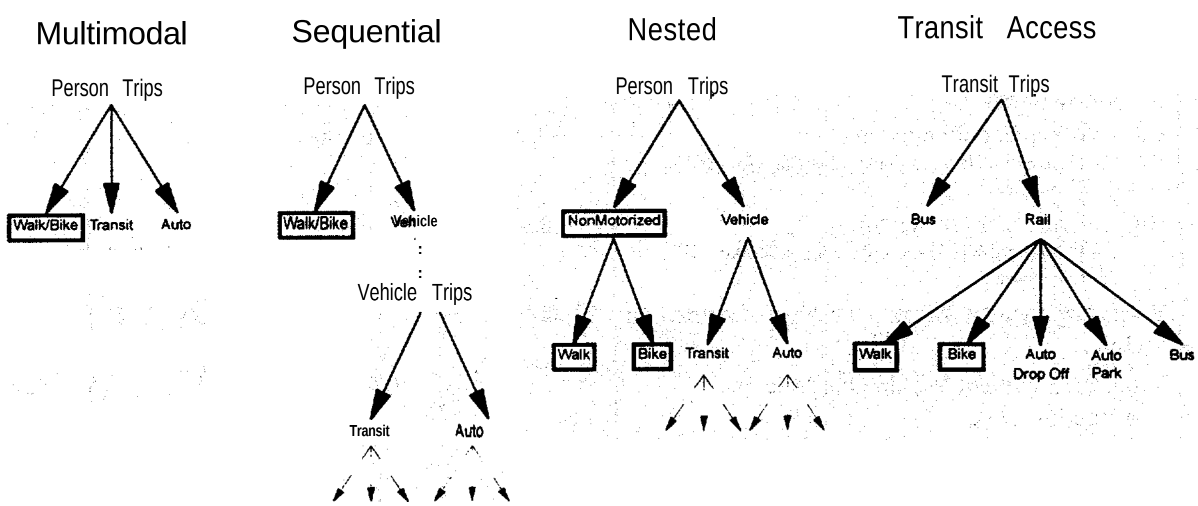
Transit access/egress characteristics for mode choice can be entered into the mode choice model as vectors of network independent zone characteristics and do not have to be traced from the coded transit network. There is no major difference in the calculations that are required, however. Households at the block level, for example, can be used to locate a home centroid for a zone, or they can be combined with transit network coordinates to directly estimate average home to transit distances in the zone.

Estimating transit access/egress characteristics is, without doubt, a good GIS application. If sidewalk information is available as a coverage in the GIS, walking distances to stops and stations can even be measured along a sidewalk network. Block coverages for GIS and block level data for population and households are available from the census. Population and household densities can, therefore, be determined by fairly small geographic units in areas that have reasonable transit service. In northeastern Illinois, the Illinois Department of Employment Securities provides an address file of nearly all employment by Standard Industrial Code, which can be located to blocks.

Nonmotorized-Vehicle Mode Choice Models With Urban Design Variables

A few MPOs have developed mode choice models that include nonmotorized modes as an alternative to vehicle modes. All of these are logit mode choice models, but different model structures have been employed. Figure 4 illustrates several mode choice model structures that have nonmotorized alternatives. Regardless of the structure of the mode choice model, including nonmotorized modes in mode choice requires an estimate of the utility associated with walking and bicycling.

Figure 4. Alternative Mode Choice Models With Nonmotorized Modes



A sequential nonmotorized-vehicle mode choice model was used in the Portland, Oregon, LUTRAQ project[2]. Trips are first split into nonmotorized and vehicle trips, followed by a subsequent split of vehicle trips into different vehicle modes. The reference utility associated with the nonmotorized choice is zero, while the vehicle utility includes independent variables that measure employment densities at the attraction end of the trip, as well as a pedestrian environment factor. Model variables and coefficients for vehicular utilities are listed in Table 2.

The pedestrian environment factor used in the Portland model has four components. These are: (1) sidewalk availability; (2) ease of street crossing; (3) connectivity of the street/sidewalk system, and; (4) terrain. Every zone is given a score between one and three for each of these four components, resulting in a combined pedestrian environment factor for each zone that ranges between four and twelve. The employment variables depend upon the type of trip, but are similar in that all three employment variables measure the amount of employment within one mile of the attraction zone.

[2] Cambridge Systematics, Inc.; S. H. Putnam Associates; Calthorpe Associates; Parsons, Brinckerhoff, Quade and Douglas, Inc. *Making the Land Use, Transportation and Air Quality Connection: Volume 4: Model Modifications*. 1000 Friends of Oregon, November, 1992.

Table 2. Vehicle Utility Equations in the LUTRAQ Study

Variable	Home Based Work	Home Based Other	Nonhome Based Work	Nonhome Based
Trip Distance	0.705	0.686	1.998	0.717
Household Car Ownership I = If Household Owns Car 0 = No Vehicle		-2.205		
Low Worker Car Ownership I = Household Has Less Than One Car/Worker 0 = Otherwise	-0.954	-0.600		
High Worker Car Ownership 1 = Household Has One or More Cars/Worker 0 = Otherwise	0.408			
Total Employment Within One Mile of Attraction Zone	-0.0000 19 I		-0.0000205	
Retail Employment Within One Mile of Attraction Zone		-0.000 135		0.000778
Nonretail Employment Within One Mile of Attraction Zone				-0.000 142
Pedestrian Environment Factor	-0.0632	-0.0620	-0.178	-0.167
Bias Constant	1.717	2.697	3.718	3.597

The Sacramento Area Council of Governments[3] developed a set of multimodal logit mode choice models that have walking and bicycle submodes. Independent variables in these models include a pedestrian environment factor. identical to the LUTRAQ variable and employment within one mile of the attraction zone. A variable called "partner density," measures both the density of households at the home production zone and density of employment at the work attraction zone in the shared ride mode utility. It is calculated as the log of the number of households within one mile of the home zone times the log of employment within one mile of the work zone.

A variable similar to the LUTRAQ pedestrian environment factor was developed by the Maryland National Capital Parks and Planning Commission[4,5]. This variable appears in the walk/bike transit access utility in a nested mode choice model for home to work trips. It is an index that measures the pedestrian and bicycle environment and includes the factors listed in Table 3. The index ranges from zero to one, with higher values indicating more pedestrian/bicycle friendly environments.

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[3] DKS Associates. *Sacramento Area Travel Demand Model: Mode Choice Submodel.* Working Paper 2, Sacramento Area Council of Governments, July, 1993.

[4] M. Replogie. *MNCPPC 1988 Logit Mode Choice Model for Home to Work Trips.* Maryland National Parks and Planning Commission, April; 199 I.

[5] Cambridge Systematics, Inc. with Barton-Aschman Associates. *Short-Term Travel Model improvements.* Final Report, Travel Model Improvement Program, Technology Sharing Program, U.S. Department of Transportation, October, 1994, p. 3-3.

Table 3. MNCPPC Walk/Bike Index Factors.

Factor	Weigl
Sidewalks	
No Sidewalks	.00
Discontinuous, Narrow Sidewalks	.05
Narrow Sidewalks Along All Major Streets	.15
Adequate Sidewalks Along All Major Streets	.25
Adequate Sidewalks Along Most Streets With Some Off-Street Paths	.35
Pedestrian District With Sidewalks Everywhere, Pedestrian Streets and Auto Restraints	.45
Land Use Mix	
Homogeneous Land Use Within Easy Walking Distance	.00
Some Walk Accessible Lunch Time Service Retail in Employment Centers	.10
Mixed Land Use at Moderate Density	.20
Mixed Land Use at High Density	.25
Building Setbacks	
Mostly Setback Sprawled Campus Style	.00
Mixed Campus Style But Clustered With Bus Stops Within Walking Distance	.05
Few or No Building Setbacks From Streets With Transit	.10
Transit Stop Conditions	
No Shelters	.00
Some Bus Stop Shelters	.05
Widely Available Bus Stop Shelters	.10
Bicycle Infrastructure	
Little or None	.00
Some Cycle Paths or Routes	.05
Many Cycle Paths, Lanes, or Routes Forming Network	.10

Several vehicle-nonmotorized mode choice models have been calibrated for northeastern Illinois for home to work, 'home to nonwork, home to transit and non-home trips[6]. The motorized alternative has a reference utility of zero in these models. Variables in the utility for nonmotorized modes' and calibration coefficients are in Table 4..

Table 4. Variables and Coefficient& for Nonmotorized Modes' Utility in CATS' Models

	Trip Categories			
	Home to Work	Home to Transit	Home to Nonwork	Nonhome
X+Y Distance	-1.25	-2.02	-1.49	-1.83
Vehicles per Worker in Household 1 = More Than One Car/Worker 0 = Less Than One Car/Worker	-1.43			
Vehicles per Adult		-1.72	-3.45	
Trip Pedestrian Environment	0.039	0.04 I	0.016	0.08 l
Bias	-0.66	1.73	0.98	-1.59

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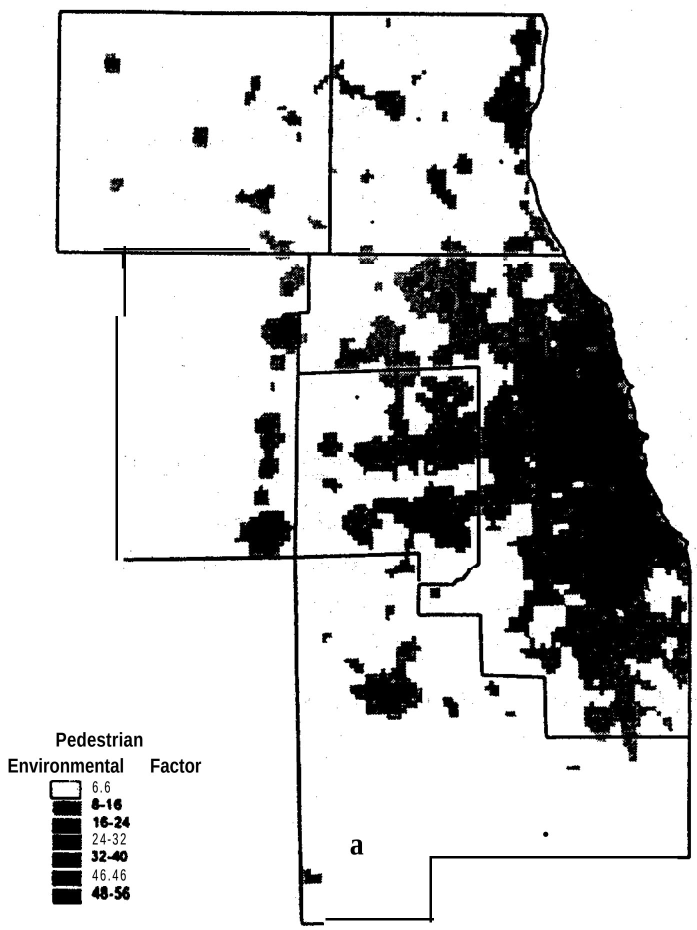
6 Ronald Eash. "Enhancing Public Transportation and Nonmotorized Modes' Performance in the Regional Transportation Planning Models. " *Proceedings, Metropolitan Conference on Public Transportation Research,* University of Illinois at Chicago, June, 1996.

The signs on the calibrated model coefficients appear correct. Longer distances reduce the utility of the nonmotorized choice. Higher household vehicle ownership should make nonmotorized travel options less attractive. Improved walking and biking conditions, measured by the trip pedestrian environmental factor, increase the utility of the nonmotorized alternative.

The pedestrian environment factor is a zone level measure of the walking and biking environment. It is the number of census blocks in a quarter-section, and it is a surrogate variable that replaces a survey of pedestrian and bicycle facilities. Figure 5 is a map showing quarter-section Pedestrian Environment Factors (PEFs).

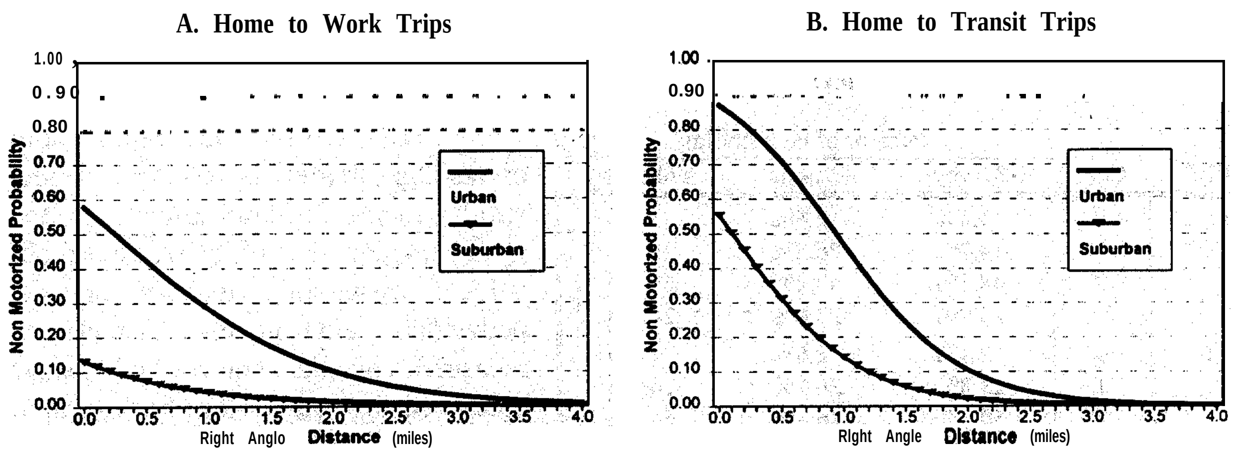
Figure 5. Pedestrian Environment Factors



Highest PEFs are located in the central area, where a one-sixteenth of a mile street grid produces the maximum PEF of sixty-four, A city neighborhood with streets in a one-eighth by one-sixteenth mile pattern has a PEF of thirty-two. Established suburban areas have PEFs ranging from ten to twenty, while newer suburban areas without regular street patterns may have PEFs of five or less. For the mode choice models, the PEFs are averaged over the quarter-sections in the rectangle formed by the trip's origin and destination.

Some model results are shown in Figure 6 to evaluate whether the models' variables seem appropriate. The probability that trips of different lengths are by walk/bike modes. is shown for typical suburban and urban households' trips. On the left is home to work trips, on the right, home to transit trips. The urban household used in these mode choice calculations has one auto shared by two drivers, while in the suburban household every driving adult has a vehicle, Average trip PEFs are twenty-five for. urban areas with a good pedestrian walking and bike environment and five for suburban areas that are- less well suited for nonmotorized travel.

Figure 6. Predicted Nonmotorized Mode, Share for Typical' Households



A different urban design variable that could be used in mode choice modeling was developed for a study of suburban centers[7]. It is a land use entropy type variable that measures the mix of activities in an area. In the referenced study, it is defined as:

$$\text{Land Use Entropy} = -\sum_i LU_i * \log_{10}(LU_i)\,.$$

In this equation, LU_i is the proportion of floor space in one of four land use categories, office, retail, housing and other. This entropy measure ranges from zero when only one land use activity is present in the zone to 0.60 when an equal amount of floor space is allocated to the four activities.

The Impact of Urban Design. on Household Vehicle Ownership

An alternate way to introduce urban design variables into mode' choice models is through household car ownership, which often appears as an independent variable affecting mode choice. In the LUTRAQ study, the previously discussed Portland pedestrian environment factor was included in an enhanced household vehicle ownership model.

[7] Robert Cervero. America's Suburban Centers: *A Study of the Lund Use-Transportation Link* Final Report, Technology Sharing Program, U. S. Department of Transportation, January, 1988. p. 57.

The Portland household auto ownership model is a logit discrete choice model, where each choice is a level of household auto ownership. The utility of a household auto ownership level is calculated in much the same way that mode choice utilities are calculated in a logit mode choice model. In the original Portland model, household auto ownership utility was a function of household size, workers in the household, household income level, and the number of employees within thirty minutes of transit travel time of the household. The enhanced household auto ownership model has a revised income variable and includes the PEF variable.

Table 5 is reproduced from the *Model Modifications* LUTRAQ report[8]. It compares the original household vehicle ownership model and the enhanced model with survey data. Higher auto ownership levels are clearly associated with lower PEFs and the PEF variable consistently improves the fit of the model to survey data.

Table 5. LUTRAQ Auto Ownership Model Results

		Percent of Households		
PEF	Cars	Survey	Original	Enhanced
0 to 5	0	1.5%	2.4%.	1.7%
	1	24.2%	26.2%	24.1%
	2	48.3%	47.4%	49.4%
	3+	25.9%	24.0%	24.7%
6	0	2.4%	2.6%	2.4%
	1	23.8%	26.7%	26.0%
	2	50.9%	46.3%	46.7%
	3+	22.8%	24.3%	24.9%
7 to 9	0	7.3%	6.8%	6.8%
	1	36.6%	35.1%	35.6%
	2	40.9%	41.3%	41.1%
	3+	15.2%	16.9%	16.6%
10 to 12	0	12.7%	11.5%	12.8%
	1	38.8%	38.2%	39.0%
	2	36.5%	37.4%	36.0%
	3+	12.0%	13.0%	12.2%

The CATS household auto ownership model is a logit model similar to the Portland model. In the CATS model, the utility of household vehicle ownership depends on the pedestrian environment, which is measured by the number of census blocks in the quarter-section and auto work trip mode share. For calibration, the auto mode share is calculated from the census journey to work data, although in planning applications it would likely come from the mode choice model. It is the number of workers driving, sharing a ride or taking a taxi divided by the total number of workers.

Figure 7 illustrates the behavior of the model for some typical households. These households feature different numbers of workers and nonworking adults and income levels. The distinction between urban and suburban locations is created by different pedestrian environmental factors and auto mode shares. The urban household vehicle ownership examples assume an auto work trip mode share of forty percent and a PEF of twenty-five. Suburban households are located in areas with a ninety percent auto mode share and a PEF of five.

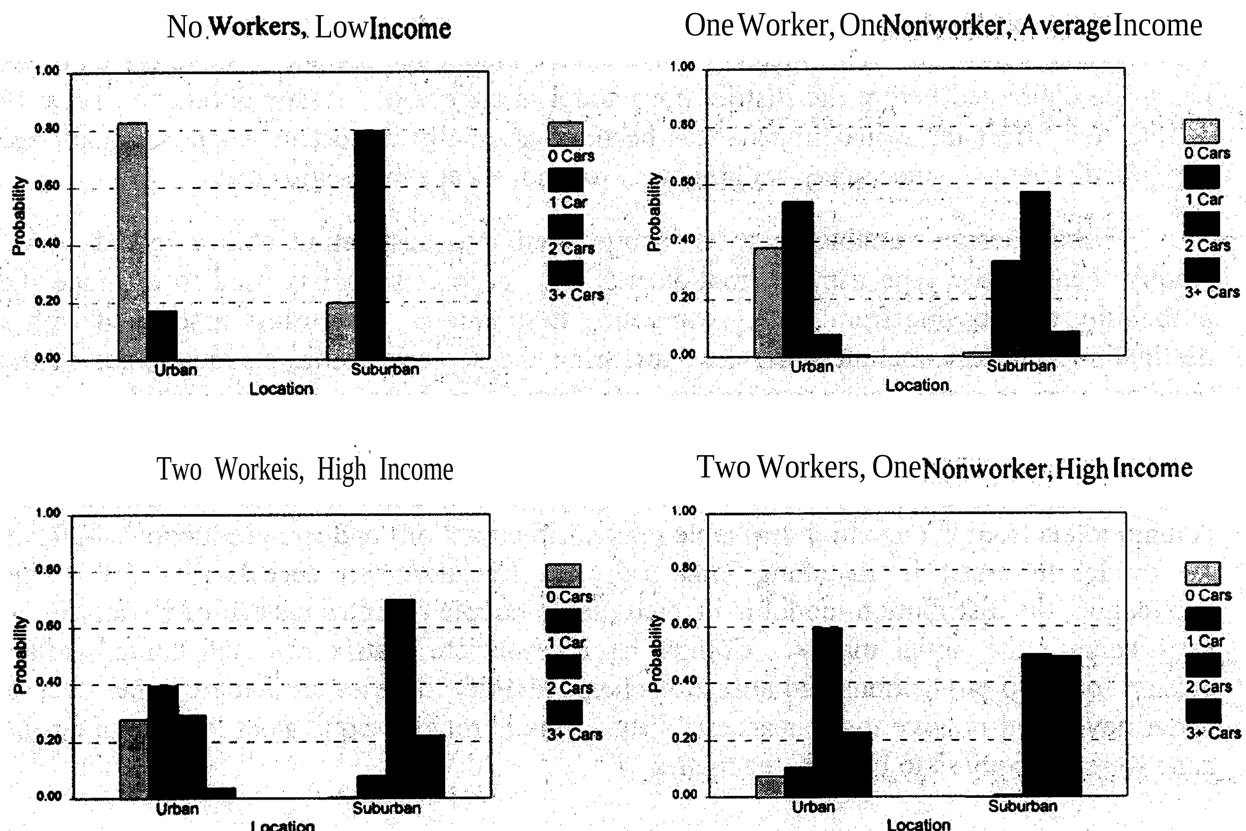
Influencing Destination Choice With Urban Design Variables

Most trip distribution models involve matrix balancing. These models have common inputs, an initial matrix to be balanced, trip productions at origin zones, and trip attractions at

[8] Loc. cit. p. 14.

destination zones. The matrix to be balanced- can be an existing, trip table. (growth factor methods), some function of zone to zone travel impedances (gravity models), the trip attractions between origin zone and destination zone (opportunity models),' or the probability of an origin zone's trip selecting a destination zone (destination choice models). After the matrix balancing is completed; the models output ,a balanced matrix: and the origin and destination zone weights that are required-to, balance. the. matrix The balanced output matrix is a trip table whose row and column sums equal zone trip productions and attractions.

Figure 7. Predicted Vehicle Ownership for Typical Households..



Even today, the vast majority of trip distribution models employed by MPOs distribute vehicle trips using travel impedances based upon highway 'travel times. This approach clearly has to change if alternative urban designs are to. have 'some, impact upon trip distribution. Strategies to increase, nonmotorized travel cannot be., reflected in trip tables, since only vehicle trips are distributed. Further; one can adjust land use 'to locate more trip productions and attractions in zones that have transit service, but there is no reason to expect these trip. productions and attractions to link together into trips that' can be served by transit when zone to zone impedances in the model are only highway based.

There is a fairly well established approach for using the composite impedance from a mode choice model in a gravity type distribution model[9]. If the mode choice model is a nested model than even changes in transit access will affect trip distribution: when this composite impedance is used in the distribution model. For example, improved walk access to transit increases the logsum transit access. variable that is part of the overall transit utility. This makes transit a more attractive choice than previously, which reduces the logsum transit and highway composite impedance used in distribution. Distributed trip interchanges between the zone with the improved transit access and ail zones that can be reached by transit would then increase, essentially increasing the overall market for transit.

If vehicular and nonmotorized trips are distributed, the zone to zone composite impedance used for distribution has to measure the difficulty of travel by nonmotorized, as well as vehicular modes. This means a mode choice model that includes nonmotorized travel has to be calibrated before the distribution model is calibrated. Assumptions and network coding that affect intrazonal impedances, become especially important when nonmotorized trips are distributed, since. many walking trips will not escape the origin zone.

Urban design variables can be incorporated into destination choice models more readily than gravity type trip distribution models. A logit model is used to estimate the probability of choosing from among competing destinations. The utility associated with a destination zone can include variables measuring the socioeconomic characteristics of the traveler, zone to zone travel impedances and destination zone attributes, including urban design variables comparable to those used in mode choice.

Relaxation of the two constraints usually placed upon trip distribution-that row and column totals from the resulting trip table match trip attractions and trip productions-allows the model to assist in matching land use with transportation accessibility. For this application, the distribution model is iterated only a couple of times instead of attempting to fully balance the initial matrix. Comparing intermediate matrix row and column totals against zone trip productions and attractions helps identify those zones that are either over or under developed relative to their accessibility. This is roughly equivalent to examining the zone weights required to balance the matrix.

Household Trip Generation's Sensitivity to Urban Design Variables.

Several tests were carried out to evaluate the sensitivity of the CATS household trip generation model to the household environment variables in the agency's auto ownership model. These sensitivity tests only show how the model responds when these variables change, and should not be interpreted as policy testing. The 1990 base household trip generation was pivoted by decreasing the auto work trip mode share, and/or increasing the pedestrian environmental factor ten percent for all households in the region. Both these changes act in the household vehicle ownership model to decrease the' number of cars available in a household.

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[9] Cambridge Systematics, Inc. with Barton-Aschman Associates, Inc. "Advanced Travel Demand Forecasting." Course Notes, NHI Course Number 15254, May, 1996.

Table 6 summarizes the results of these sensitivity tests. Perhaps the most surprising result is. that the number of trips generated by households is fairly insensitive to these two variables. Total household trip generation (motorized plus nonmotorized trips) does decline with reduced household vehicle ownership, but this, relationship is much weaker than the relationship between vehicular trip generation and vehicle ownership.

Some changes in household trip making due to lower vehicle ownership levels are still apparent. Trips by workers tend to change less than trips by nonworkers in the household. The implication is that a nonworking adult makes use. of "excess" vehicles in the household not required for work trips. Trips between workplaces decline somewhat more than other trips made by workers because private auto is most often used by workers, such as salespersons, who travel between work locations. Shopping trips from work made by workers are nearly constant, while other shopping trips from home decrease.

Table 6. Sensitivity of CATS Household Trip Generation to Work Trip 'Auto Mode Share and Pedestrian Environment

	Trips Produced by Households (1000s)						
Trip Purpose	1990 **Base**	**-10% Auto Mode Share**		**+10% Pedestrian Environment Factor**		• 10% Auto Mode Share **and +10% PEF**	
Worker							
Home to Work	6,276	6,267	-0.1%	6,269	-0.1%	6,260	-0.3%
Home to Shop	1,256	1,250	-0.55%	1,251	-0.4%	1,245	-0.9%
Home to Other	3,026	3,014	-0.4%	3,015	-0.4%	'3,003	-0.8%
Work to Shop	350	351	0.3%	350	0.0%	350	0.0%
Work to Other	1,307	1,298	-0.7%	1,300	-0.5%	1,291	-1.2%
Work to Work	931	914	'-1.8%	919	-1.3%	901	-3.2%
Nonhome/Work	1,085	1,079	-0.6%	1,080	-0.5%	1,073	-1.1%
Nonworker							
Home to Shop	1,345	1,319	• 1.9%	1,325.	-1.5%	1,300	-3.3%
Home to Other	2,846	2,813	-1.2%.	2,825	-0.7%	2,791	-1.9%
Nonhome	1,076	1,047	-2.7%	1,055	-2.0%	1,026	-4.6%
Child							
Home to Nonhome	591	587	-0.7%	587	-0.7%	582	-1.5%
Total	**20,090**	**19,941**	**-0.7%**	**19,976**	**-0.6%**	**19,824**	**-1.3%**

Simulation Models

This last section briefly looks at trip simulation as an alternative to the conventional four step travel demand models. Trip simulation offers an advantageous framework for considering the impacts of urban design 'variables upon travel behavior since it reduces the need to average model input variables across analysis zones. One of the features of the TRANSIMS framework is its simulation of individual travelers between trip origins and destinations, rather than between zone centroids[10].

[10] C. Barrett, K. Berkbigler, L. Smith, V. Loose, R. Beckman, J. Davis, D. Roberts, and M. Williams: *An Operational Description of TRANSIMS.* Los Alamos National Laboratory; June, 1'995.

The CATS mode choice model is a simulation model that was originally developed in the 1970s[11]. Figure 8 summarizes the essential logic of the model. There are three major nested logic loops in the model, incremented by origin zone, destination zone and person trip. Four sets of calculations are completed for each person trip: (1) auto operating costs based on average travel speed and distance traveled; (2) transit access and egress costs and times to be combined with the transit line-haul data input into the model; (3) non-CBD auto parking costs and walking times at the beginning and end of the trip, and; (4) CBD parking costs and destination walk time when the destination zone is a CBD zone

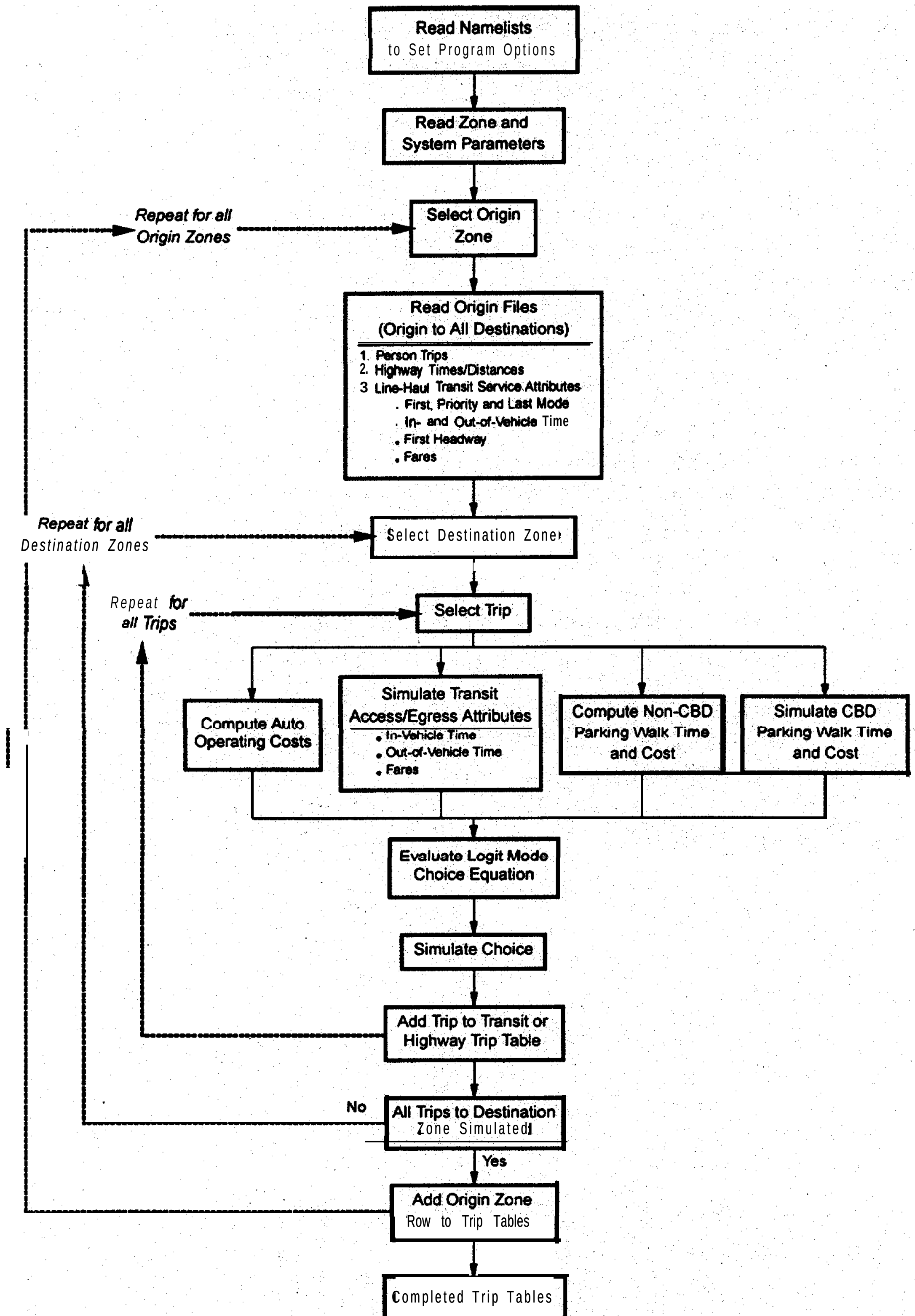
The transit access-egress and CBD parking, submodels are Monte Carlo simulations that generally work in the same fashion. They obtain an access-egress characteristic for a trip, such as distance from home to a rail station, by randomly sampling a distribution of the access-egress characteristics. For the distance between home and a rail station, the frequency distribution of station access distances weighted by all households in a zone is sampled.

Access-egress times and costs for auto'and transit are combined with the modal line-haul times and costs and entered into a logistic equation, which calculates the probability that the trip is by transit. Since trips between the same two zones can have different access-egress characteristics, the transit mode choice probability can vary for each trip between the same pair of zones, just as it does in the realworld for individuals traveling between the same two zones. A trip is then assigned to either transit or highways using another Monte Carlo simulation. Transit and auto trips are finally accumulated for the interchange.

This variability in zone transit access-egress time and cost corresponds to the distribution of trip origins and destinations within zones. Simulating access-egress characteristics in this way gets around the theoretical problem of using zone, level average access times and costs, which can be unrepresentative of the actual conditions faced by transit users. It also provides a convenient means of representing different spatial relationships between activities by varying the distributions of transit access/egress characteristics.

[11] Yehuda Gur, Elizabeth Lowe, Anant Vyas, and Eugene Ryan. "Urban Modal Split Modeling Using Monte Carlo Simulation." Chicago Area Transportation Study, 1973.

Figure 8. CATS Mode Choice Model's Logic



A SYNTHETIC APPROACH TO ESTIMATING THE IMPACTS OF TELECOMMUTING ON TRAVEL

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ABSTRACT

A multiplicative model is proposed as a framework for examining the current state of knowledge in forecasting the demand for telecommuting and the resulting transportation impacts. A running illustrative example (containing a base and a future case) is developed, using plausible values for each factor in the model. The base case suggests that 6.1% of the workforce may be currently telecommuting (at least in California), 1.2 days a week on average, with the result-that 1.5% of the workforce may be telecommuting on any given day. It is estimated that the vehicle-miles eliminated by this'level of telecommuting constitute at most 1.1% of total household vehicle'travel. When-the limited knowledge about 'potential stimulation effects of telecormnuting is incorporated, it is estimated that the net reduction falls to at most 0.6% of household travel. Reductions in the future could besmaller as commute distances of telecommuters fall closer to the average and as the stimulation effect grows. In any event it is likely that, due to counteracting forces, the aggregate travel impacts will remain relatively flat well into the future, even if the amount of telecommuting increases considerably.

1. INTRODUCTION

The potential of telecommunications to mitigate urban traffic congestion' and improve air quality through reducing the need to travel has in recent years captured the attention of public planners and policy-makers. The application of telecommuting offers particular appeal since it addresses a number of other policy issues such as the "family friendly" workplace (Gordon, 1996a) and employment opportunities for mobility-limited sectors of the labor force (Hesse, 1995). Mokhtarian (199 1 b) lists examples of policy statements supporting telecommuting from the state governments of California, Washington, Florida, and Virginia as well as the Federal Government (Bush Administration). Since that time, similar laws,' resolutions, and proclamations have been adopted by 'the states of Arizona (Gordon, 1996b), New Jersey (Gordon, 1992), Georgia (Gordon, 1993), 'and Minnesota (proclamation by Governor Carlson declaring the week of May 13, 1991 to be "Telecommuting Week"), among other activities at local, state, and federal levels. At the federal level, the Clinton Administration recently released the *President's Management Council National Telecommuting Initiative Action Plan* (November, 1995), which calls for an increase in the number of Federal government telecommuters 'from about 4000 to 60,000 by the end of fiscal year 1998 (about 3% of the civilian federal workforce).

A number of regional planning agencies are considering what the likely impacts of telecommunications on future travel might be and how to incorporate those impacts into the conventional transportation demand forecasting process. Occasionally some agencies must overtly confront the question of whether those impacts will be of such a magnitude as to affect (reduce) the need for new infrastructure capacity. The following comment by a planner with the Austin, Texas, metropolitan planning organization is not atypical:

> "Is it possible to forecast how telecommuting will affect transportation by the year 2020? We have members of the Austin community who insist that the light rail line which is in the planning process and roadway expansions are not necessary due to the significant future levels of telecommuting. While we believe that the technology will continue to advance at a rapid pace, human acceptance of this technology as an alternative to physical travel is questionable. Any light you can shed on this subject... would be most appreciated. It is difficult to plan a transportation system which takes into account the use of telecommuting when future levels of diffusion are difficult to assess" (e-mail communication from David Mann to Gil Gordon, October 6, 1995).

One government study (US DOE, 1994) estimates that telecommuting in the 339 largest US cities (accounting for two-thirds of its population) could eliminate the need for 7,300 - 11,200 lane-miles of freeways and major arterials by the year 20 10, for an (undiscounted) cost savings of $13 - 20 billion. Another study (US DOT, 1993) estimates that nationwide, telecommuting could result in 408 - 815 lives saved and 58,850 - 117,700 accidents avoided by the year 2002 due to reducing travel. The same study estimates travel time savings by telecommuters at 826 million to 1.7 billion hours in 2002. Yet another study, by a respected consulting firm, calculated the nationwide benefits of an expected 10-20% substitution of travel by telecommunications to include 1100 lives saved, 1.6 million accidents avoided (saving $3.9 billion), 3.1 billion hours of time saved, and about $600 million in infrastructure maintenance cost savings (Boghani, et *al.,* 199 1; Boghani, 1992).

Are these expectations realistic? With numbers such as these under serious discussion, reliable information on the travel impacts of telecommunications would appear to be highly valuable to agencies at all levels of government.

Over at least the past decade, a number of overviews of the impacts of telecommunications on travel have appeared, both conceptual (Salomon, 1985; Mokhtarian, 1990) and empirical (Nilles, 1988; Mokhtarian, 199 1 b; Mokhtarian, *et al., 1995).* Most of the empirical research has focused on telecommuting, probably because (1) it has been feasible for longer than most other "tele-applications" (such as videoconferencing or on-line shopping), (2) it has the appealing side benefits alluded to above, and (3) the- prospect of eliminating or reducing the peak-period commute trip is especially attractive. Although its share of total trips (but not miles) is declining, commuting still accounts for more trips (26% in 1990) and miles traveled (32%) than any other single purpose (Hu and Young, 1992). Also, it may well be the case that a higher proportion of commute trips than other types of trips will be amenable to substitution through telecommunications. Both factors combined mean that telecommuting probably has the highest potential for travel reduction. of any of the,. tele-applications, which undoubtedly justifies .a continued. interest in the study, of its adoption and impacts;

Even-though the most recent review of the impacts of telecommuting, on, travel was published in just 1995, considerable empirical research has occurred since the time that paper was written (1992-3), much of which is only recently published, still in press, or still inprogress. This body of research offers extensive insight into the impacts of telecommuting on travel, and it would be productive to bring together and place in context many of those individual findings. The present paper attempts to assemble the substantive. findings to date under a unified framework,- The framework is a simple, multiplicative model, the factors of which represent various elements critical to forecasting the transportation impacts of telecommuting. Each factor is itself the subject of separate research efforts.

The New American, Webster Dictionary defines "synthetic" as (1). 'Ipertaining to or based on synthesis"; i.e. on "the combination ofseparate elements, into a complex whole", or (2) "artificial?. I refer to the framework presented in this paper as a "synthetic approach to estimating the impacts of telecommuting on travel" in both, senses: of the word. Certainly it represents a complex combination of separate elements; but that combination will of necessity be somewhat artificial, precisely because of the complexity of the relationships involved: At the same time; the approach offers a basis for getting to the "bottom line" that is both readily understood by, practitioners and based on the best research to date. It further makes very-clear the areas in which, additional research is needed and to some extent implicitly suggests the specific form that such research might take. In any application. of the model,-each factorcan be updated as better information becomes available. Depending on .the context,; "better!, may -mean more broadly representative or more locally specialized.

The following section focuses on the portion of the. framework relating to estimating the amount of telecommuting that occurs on any given day. Section-3 continues the framework to account for the impact that a given-level of telecommuting will have on travel Section 4 summarizes the preceding discussion and examines fruitful directionsfor future research.

2. FACTORS IN-ESTIMATING THE AMOUNT OF TELECOMMUTING

2.1 A "Simple" Model of Telecommuting Levels

The amount of telecommuting that occurs on any given day, independent of its transportation impacts, will itself be of interest to a number of parties besides transportation planners – for example, to providers of telecommunications services to the home. That amount. is:literally the product of a series offactors. Who *can* do it? Of those who can, how many *want* to do it?- Of those who can and want to, how many *will* do it?. Of those, how *often* will they telecommute, and for *how long?* Specifically, let

E = an average number of people employed within a certain time frame,
A = the proportion of workers who are able to telecommute,
W = the proportion of those able to telecommute who" want to,
C = the proportion of those able and wanting to telecommute who choose to, and

F = the average frequency of telecommuting, expressed as a fraction of a five-day work week (for example, telecommuting two days a week means doing so 40% of the time, or a frequency of 0.4).

Then the expected number of people who are in a period of active telecommuting at any given time can be estimated by

$$T = E \times A \times W \times C.$$

The average number of people telecommuting on any given day, that is the expected number of telecommuting occasions, is estimated by

$$O = E \times A \times W \times C \times F = T \times F.$$

The numbers T and 0 illustrate the -difference between the concepts of telecommuting ***penetration*** and ***levels,*** respectively, discussed in Handy and Mokhtarian (1995). Obviously E can be omitted from both equations if the focus is on the proportion of the workforce rather than on the actual number telecommuting, but for some applications (notably, in assessing the facility-specific impacts of telecommuting, whether on communications or transportation networks, since network capacities are absolute rather than relative quantities) knowing the actual number is critical.

The most important thing to realize about the above definitions is that each one represents the expected value of a random variable. The true expected number of people telecommuting on any given day is the expected value of the product of those underlying random variables. Now, if all the random variables implied by the above definitions were independent, then the expected value of the product would equal the product of the expected values, and the expressions given for T and 0 would be exact equations. To the extent that the various factors are correlated, however, that equality does not hold, and the expressions given for T and 0 are only approximations of the true expected values. It cannot be emphasized strongly enough that a failure to properly account for interactions among the various factors can result in estimates of telecommuting that could .be wildly inaccurate ***in either direction;*** Some of the important likely interactions and their impacts on the model will be examined in further detail below, and the concluding section of the paper discusses refining the simple model presented here to more formally account for correlations among variables.

Thus, the apparent "simplicity" of the equation for 0 is (not surprisingly) somewhat illusory: first because of the interactions mentioned above, and second because each factor in the equation can be thought of as the outcome of a separate complex model - with uncertainties of measurement and forecasting - in its own right,.

Nevertheless, this model is conceptually similar to the "demand, decomposition" approach commonly taken by marketers and adopted by Gautschi and Sabavala (1995) to analyze the demand for automobiles and telephones in the early years of their introduction. Gautschi and Sabavala use the simple equation $S = N \times T \times R$, where S is sales volume, N is the size of the potential market, T is the fraction of potential customers who actually buy, and R is the average number of transactions per person.. Their S roughly corresponds. to our O (number- of telecommuting occasions), their N to our E×A (number of people able to telecommute), their T to our W×C, and their R to our F (intensity of telecommuting by those who do so). Salomon (1994) also used a similar approach to forecast the amount of telecommuting (and consequent trip reduction) for. the Tel-Aviv metropolitanarea in the year 2020. The current approach is not specifically based on Salomon's, and it is operationalized with empirical data not available at that time, but the two studies inevitably have some conceptual congruence.

The next four subsections of this paper respectively discuss what is known about the factors A, W, C, and F. For the purposes of illustration, plausible values for each quantity are suggested based on the discussion, and combined to compute hypothetical values of T and 0. Table 1 contains each variable defined throughout the paper, and the illustrative values for each. A value of one million is used for E, as a convenient unit which can be scaled up or down for a specific metropolitan area. The astute reader will have noticed that the question, "How long?", at the beginning of this subsection was not matched by a. factor in the equations for T and 0. The reason for this is explained in Section 2.6, The final subsection discusses the combined outcome of all the factors presented in this, section.

2.2 Who Can?

A starting point for calculating the size of the universe of potential telecommuters is sometimes taken to be the number of information workers in the workforce, with the proportion of such workers in the. U.S. estimated to be somewhere above 50% now and as high as 70% in the future. This approach, which essentially equates information worker status with job suitabifity for telecommuting, errs in being both too broad, and not broad enough,,. It is 'not broad enough because many jobs which would not be considered information work contain a sufficient number of information&based tasks to make them telecommutable to some extent (Mokhtarian, 199 1 a, b). Hence, based on the evidence of actual telecommuting, the universe of potential telecommuters should include occupations such as restaurant inspectors, probation officers, and home health care workers.

On the other hand, taking the universe of potential telecommuters to. be information workers, is in another sense too broad, for two reasons. First, not all information worker jobs are amenable to telecommuting. A number of studies recognize this, but the estimates of the proportion of jobs for which this is true have, been largely judgmental. For example, Nilles (1988) assumed that 20% of information jobs would not be telecommutable. Salomon (1994), on the other hand, estimated that proportion to be around 49%. There are at least two.empirical pieces of evidence. One study of628 employees, 95% of whom were information workers and Salomon, 1996a). In a sample of 686, similarly dominated by information workers, Mahmassani, et *al.* (1993) found that 38% believed their job was not suitable for working from

TABLE 1
SUMMARY OF KEY FACTORS

Variable	Definition	Illustrative Assumption or Computed Result
E	number of people employed	1 million
A	proportion of employees able to telecommute (current base case, hypothetical future case)	0.16 - 0.30
W	proportion of those able to telecommute who, want to	0.50
C	proportion of those able and wanting to who choose to telecommute	0.76
T	= E×A× W ×C, the (estimated) expected number who are in an active period of telecommuting	60,800 - 114,000
F	average frequency of telecommuting (fraction)	-0.24
O	= E×A× W×C×F = T×F, the (estimated) expected no. of telecommuting occasions on any one day	14,592 - 27,360
D	average round-trip drive-alone commute 'distance (base case, future)	47-27
a	proportion of telecommuting occasions eliminating a vehicle commute trip	0.72
V	= O×αD, the total (commute) vehicle-miles eliminated on a given weekday (low 0 × high. D, high 0 × low D)	493,793 - 531,878
	αD / M,, the proportion reduction in VMT for a telecommuter on a telecommuting day (base case, future)	0.65 - 0.53
	αD×F / M,, the proportion reduction in VMT for a telecommuter bver a five-day workweek (base case, future)	0.16 - 0.13
M_2	average total drive-aldne VMT by any' worker on an ordinary weekday	30-33

TABLE 1 (continued)		
P	population of licensed drivers $(1.22\times E)$	1.22 million
M_3	**average total** (drive-alone and **rideshare)** VMT per driver in a calendar week	**189** - 208
X	$= O\times\alpha D\times 5 \;/\; P\times M_3$, average proportion reduction in total household VMT	0.011 - 0.010
N	increase in VMT due to non-work travel generation, expressed as a fraction of V	0 - 0.073
R	increase in VMT due to residential relocation,. expressed as a fraction of V	'0
L	increase in VMT due to latent demand, expressed as a fraction of V	0.50
I	increase in VMT due to induced demand, expressed as a fraction of V	? ? ?
	$1 - (N+R+L+I)$, the proportion of V representing the net reduction in travel, taking **stimulation effects** into account	**0.50** - 0.43 (taking I = **0)**
Z	$= V - (N+R+L+I)\times V$, the net change in VMT for a given weekday	246,897 - 228,708 (taking I = 0)
	$Z\times 5 \;/\; P\times M_3$, the net change in VMT as a proportion of total travel	0.0054 - 0.0045

home several days a week. In one additional study (Brewer and **Hensher,** 1996);. job unsuitability was given as the reason for not telecommuting **by** 74% of the sample, but that sample of commuters in six Australia capitals probably. has a lower proportion of information workers than in the other two cases cited.

One difference between these high numbers **and Nilles's** lower number is that Nilles assumed that a number of jobs which **would** not be suitable for home-based telecommuting, would be appropriate for center-based telecommuting. This certainly seems. **plausible** in principle, but (1) it is not **clear** that centers would remove the job suitability **constraint** for about half of those whose jobs do not permit telecommuting **from** home (as would need to be the case to reconcile his assumed value with the two empirically-derived values **of 44%** and **38%),** and (2) the 'little empirical evidence available to date 'suggests that, workers perceive their job suitability to be higher for home-based than for center-based telecommuting (Mokhtarian, et ***al.,*** 1996b). Although this may appear to be counterintuitive, and may in fact be partially an artifact of the novelty of the telecenter concept, several workers who were interviewed specifically about this apparent discrepancy were able to give rational explanations for their answers based on the characteristics of their specific jobs. Preference for home-based telecommuting also appears to be stronger than for the center-based form at this point (Mokhtarian, *et al.*, 1996b; Bernardino and Ben-Akiva, 1996).

The second reason that equating information workers with the universe of potential telecommuters is too broad is that job suitability is only one of several constraints which preclude an individual from telecommuting. Mokhtarian and Salomon (1994) identify a number of potential constraints on the ability to telecommute: external constraints that can be related either to awareness, to the organization, or to the job, and internal psychosocial constraints. The internal constraints may be viewed as affecting the *desire* and the actual *choice* to telecommute but not, in general, the *ability* to do so. This distinction is not absolute, however: some constraints classified as psychosocial (such as household distractions) may in fact pose real external barriers to telecommuting.

Three key external constraints are lack of awareness, manager unwillingness, and job unsuitability. In the same sample of 628 described above, lack of awareness was active for 4% of the respondents, job unsuitability for 44%, and manager unwillingness for 5 1%. At least one of these three constraints was active for 68% of the sample, meaning that telecommuting was possible for no more than 32%. In view of the characteristics of the sample (predominantly information employees of an organization with an active, visible, and long-term telecommuting program supported by upper management), the prevalence of these constraints is certainly *underrepresentative* of the situation for the workforce as a whole. Mokhtarian and Salomon (1996b) estimated that, taking these three key constraints as well as other external constraints into account, telecommuting would have been feasible for 14-16% of the workforce in 1992, the year their data were collected.

Constraints can be'mitigated over time; useful questions for further research are how rapidly and to what ultimate degree. For the hypothetical example of this paper, we will take A=O. 16 as a base case, and set A=0.30 for some unspecified point in the future. By contrast, another study, focusing only on the job suitability factor, proposed 40% as a "current" (1988) floor (which was also assumed to rise over time) on the proportion of the workforce that could potentially telecommute (Nilles, 1988).

2.3 Who Wants to?

Not everyone who is able to telecommute will want to. Mokhtarian and Salomon (1994) point out that the absence of binding constraints is a necessary but not sufficient condition for telecommuting to occur. One or more drives or motivations to telecommute must also be present. Five such types of drives are identified: work, family, leisure or independence, commuting, and ideology (specifically a pro-environment orientation):

Thus, there are two reasons why not everyone who can telecommute (in terms of external constraints) will want to: a drive to do so may not be present, or, the drive(s) may be outweighed by the intensity of internal constraints such as risk aversion, interpersonal interaction needs, or the perceived benefit of the commute.

Some estimates of the proportion of workers who want to telecommute that have appeared in the literature include 88% (Mahmassani, et *al.,* 1993, sample proportion), and 50-80% (Salomon, 1994, judgmental range). In this context, however, given thestructure of the proposed model it is important to condition the desire to telecommute on the ability to do so. There is evidence that those two factors **are not** entirely independent: **in** the sample of 628 workers mentioned earlier, Mokhtarian and Salomon **(1996a)** found that -87% of those for whom telecommuting was not possible (based only on the three key external constraints described in Section 2.2) wanted to telecommute, compared to **91%** of those for whom it was possible. They also found job suitability to be the strongest and most. significant out of nine explanatory variables in a model of **telecommuting preference** (Mokhtarianand Salomon, 1.997). Hence, not unnaturally, one is less likely to want to telecommute if it is not possible to do so. However, those specific numbers are heavily influenced by the selection bias of the sample (as is the 88% figure cited above). That is, people who do not want to or cannot telecommute are less likely than others to return the survey, and hence the numbers given are overrepresentative of the population as a whole. Correcting .for that bias,. Mokhtarian and Salomon **(1996a, 1996b)** estimate that telecommuting may be "desired by as few as 46% of those for whom it is possible."

Since desire (once external constraints are controlled for) is primarily a function of psychological characteristics, there is little reason to expect large changes over time in the value of W. Hence, for the illustrative example developed here, we take **W=0.5** for both the base **and** the future cases.

At this point, several studies have modeled the preference to telecommute (including both home-and center-based forms), and it may be of interest to review characteristics found to be significant to the desire to telecommute. Such a review is beyond the scope of the present paper, but the interested reader is referred to Mokhtarian and Salomon **(1997),** Bagley and Mokhtarian (forthcoming), Stanek and Mokhtarian **(1997),** Bernardino and **Ben-Akiva (1996),** and Sullivan, *et al.* **(1** 993, a stated preference model of telecommuting frequency).

2.4 **Who Will?**

It was pointed out in Section 2.3 that even when no external constraints are binding and a drive to telecommute is present, internal constraints may be strong enough to cause telecommuting to be perceived as undesirable. In other situations, those constraints **may** not be powerful enough to overcome a preference to telecommute, but they may be sufficiently strong to prevent choice. For example, it is quite possible for someone to express a desire to telecommute based on one or more drives, but to choose not to out of a fear that it would negatively impact her promotion potential-(see, e.g., Bagley, *et al.* , *1996).* **Thus,** not everyone who can and wants to telecommute will **do so.** Based on Mokhtarian and Salomon **(1996b)** we can estimate that of the portion of the workforce for which telecommuting is both possible and preferred, about 76% will choose it. With no other known empirical evidence, we take for our example **C=0.76.**

Again, there are several studies modeling the choice to telecommute, which identify explanatory variables significant to choice. The interested reader is referred to Mokhtarian and Salomon (1996b) and Mannering and Mokhtarian (1995, the choice of telecommuting frequency).

2.5 How Often?

Whereas early treatments of telecommuting often considered it as occurring full-time or not at all, conventional wisdom holds that most telecommuting today is part time – "one or two days a week". Conventional wisdom is supported by the empirical evidence. In a review of eight home-based telecommuting studies (taking place in the late 1980s and early 1990s), Handy and Mokhtarian (1995) found an average telecommuting frequency of 1.2 days a week, or 24%. Brewer and Hensher (1996) present a distribution of telecommuting frequencies for their 1994 sample; estimating each category by its midpoint and assuming a 2 1 -workday month yields an estimated average frequency of 22%. A recent study of center-based telecommuting (Varma, *et al.,* 1996) found frequencies of 17-25% (based on data collected from 1992 to 1995).

These various estimates appear to show a fair amount of spatial and temporal stability. As Handy and Mokhtarian (1996a) point out, there are plausible arguments in either direction for the way in which the average frequency-of telecommuting may change over time. On the one hand, the early adopters of telecommuting being measured in most of these studies may be more motivated, and hence telecommute more often, than the later adopters will as telecommuting spreads. On the other hand, improvements in technology and in the comfort of both employers and employees with telecommuting may lead to greater frequencies over time. In the absence of any compelling evidence for a trend upward or downward, we suggest that average frequencies will remain stable and take $F=0.24$.

One further observation which can be made is that actual telecommuting frequency is typically less than the expected and desired frequency (Mokhtarian, *et al.*, 1996b). One sample. of 27 telecenter users (Mokhtarian, *et al.,* 1996a) reported before beginning to telecommute that they wanted to use the center 59% of the time (about three days a week) and expected to do so 50% of the time. About six months (on average) after beginning to telecommute, their actual reported frequency was 39% (two days a week). Hence, it would be unreliable to base an estimate of future telecommuting frequency on prospective self-reports without applying some kind of correction factor.

2.6 How Long?

The nature of temporal patterns of telecommuting is an important research and practical question that has received little attention to date. Once people begin to telecommute, how long do they continue to do so? Do they telecommute for a while then quit altogether, do they cycle, in and out of it at various points in their career? Why do they quit, why re-start? How often do they "exit" telecommuting to take up a home-based business, as opposed to returning to a conventional work arrangement or to some other alternative? What is the average duration of telecommuting periods, or spells, and what distribution do these periods exhibit?

Varma, *et al.* (1996) review the limited empirical data available on telecommuting duration from three, two-year home-based telecommuting programs, and present, preliminary findings from a telecenter program. Across the three home-based programs, they report that 32-60% of those originally selected to telecommute were still-doing so at the conclusion of the two-year pilot (not all of those will have telecommuted the full two years, as recruitment sometimes spread. over six months or more).. Of those originally selected (meaning that they volunteered and completed an initial, questionnaire, that their.managers approved, and sometimes that they completed a training. session), 17-53% never even telecommuted at all. The key finding on duration from the telecenter program was that 50% of its telecommuters quit within nine months after, starting.

Thus, the study of the adoption of telecommuting is unlike the case for a simple technology improvement such as a microwave oven or video cassette recorder, which is most often "permanently:' acquired. In those situations, new adopters are added to a base of existing adopters, and-penetration steadily rises. In the case of telecommuting, penetration may fluctuate somewhat over time due to attrition among previous adopters. For example, the market research firm Find/SVP, which conducts an annual survey 'of home-based work, estimated that the number of telecommuting employees in the, US fell (for the first time in the ten years during which the surveys had been taken) from 9.1 million in 1994 to 8.2 million in 1995, lower than the 8.5 million estimated for 1993 (Miller, 1995, also reported in Mokhtarian and Henderson, 1996).

Even if the measured drop in penetration is only a temporary dip in a generally rising trendline (and Find/SVP is projecting anincrease to 8.7 telecommuters in 1996), the. message seems to be that attrition among telecommuters will limit the growth in penetration to be lower -perhaps considerably lower—thanwould be expected if attrition were not accounted for.

Why do people quit? Different category labels across the -studies reviewed by Varma, *et al.* (1996) inhibit comparability, but the. most common reason (offeredin 30-63% of the cases) appears to be job changes, whether to a different job altogether or to different emphases, responsibilities, or circumstances within the same. job; (Corporate downsizing and outsourcing were also cited by Miller (1995) as some of the, likely reasons for the national decline in telecommuting). The next most common reason is apparently manager concerns (offered by about a quarter of the participants in two of the reviewed studies). -Dissatisfaction with telecommuting was mentioned rather infrequently as a reason for quitting, and most former telecommuters interviewed, in one study expressed a desire to return to telecommuting when possible.

Hence, attrition seems to be due primarily. (although not exclusively) to 'external constraints rather than to a disillusionment with the delivery. of benefits promised by telecommuting As discussed in Section 2.2, these types of constraints can be mitigated to some degree over time. The lesson here, however, appears to be (congruent with the path of telecommuting penetration itself) that although mitigation of these constraints may follow a generally upward path in the aggregate, there is likely to be considerable turnoverat disaggregate levels. That is, for an individual, constraints will be removed and reimposed at various points in time, although over time the constraints will be less often applicable to more and more people. The net result, however, is again that the growth of telecommuting may not be as rapid as expected under the view that constraints would be permanently removed for an ever-widening circle of people. In the current framework, the practical question is whether and how fast the hypothetical value of A=0.30 proposed in Section 2.2 could in fact be reached.

How should attrition among telecommuters be incorporated into the multiplicative model which constitutes the framework of this paper? In essence, it is incorporated automatically and implicitly. When people stop telecommuting, it is either because they are no longer motivated or driven to do so, or because some constraint (whether internal or external) prevents them either from being able to telecommute, from desiring to telecommute, or from choosing to do so. The effects of all of these possibilities are embedded within the factors of **A, W,** and C (and F, for that matter); to incorporate an additional duration factor would be to double-count these effects, Thus, to the extent that A, W, C, and F are accurately forecast, no further adjustment for duration should be needed.

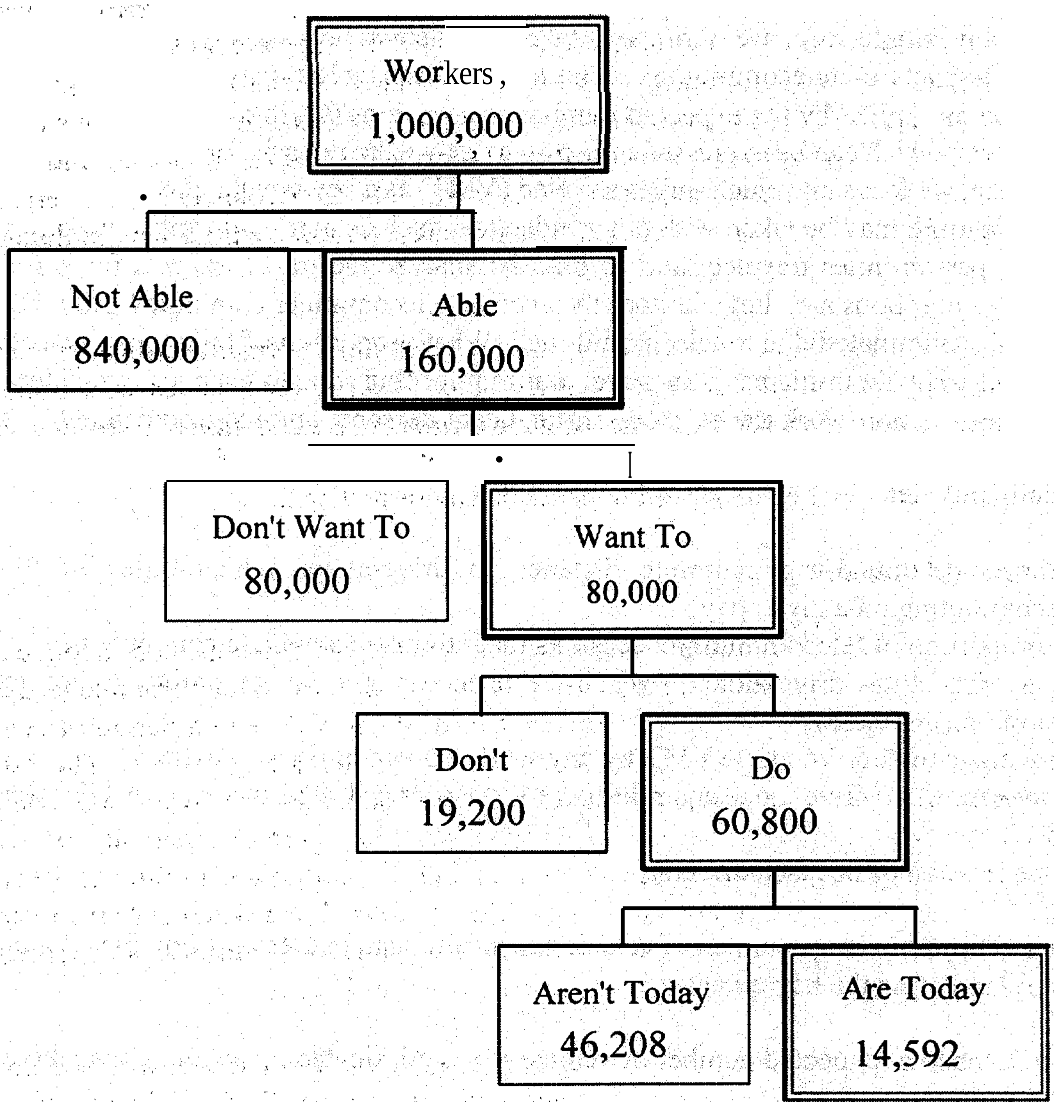
Nevertheless, the study of temporal patterns of telecommuting remains critical precisely to *improve* our ability to forecast changes in these other factors over time, as well as more generally to improve our understanding of the dynamic element in the adoption of a strategy such as telecommuting. See Kitamura (1990) for a persuasive discussion of the importance of longitudinal (panel) data in the analysis of dynamic behavior patterns.

2.7 Combined Outcome

The entries for T and 0 in Table 1 show the results of the assumptions made about each variable so far. The base case assumption that 16% of the workforce can telecommute leads to the estimate (T) that for every million workers, 60,800; of them will be in a period of active telecommuting—in other words, that 6.1% of the workforce is telecommuting. The same assumption leads further to the estimate (0) that about 14,600 or 1.5% of the workforce will be telecommuting on any given day. These numbers (illustrated in Figure 1) essentially replicate estimates of the penetration and level of telecommuting in the California workforce in 1991 (Handy and Mokhtarian, 1995). Although the relationship between T and 0 is based on the same assumed value for F in both cases, the similarity of T here to Handy and Mokhtarian's estimate is an independent outcome (noted by Mokhtarian and Salomon, 1996a).

The assumption that at some point in the future, 30% of the workforce will be able to telecommute, leads to estimates for T and 0 equivalent to 11.4% and 2.7% of the workforce, respectively. Thus, a sizable (and highly speculative) increase in the ability of workers to telecommute still results in relatively low levels of activity on any given day. It should also be pointed out that since the factors in the model were "calibrated" primarily with California data, they reflect California conditions. In view of the higher than average share of workers in "telecommuting-conducive occupations" in California (Handy and Mokhtarian, 1996a), and the

Figure 1: Telecommuting level's (base case)



extent of its congestion problems (perhaps motivating individuals to telecommute), values for A and W in particular may be lower in many other parts of the country, both now and in the future.

3. FACTORS IN ESTIMATING THE TRANSPORTATION IMPACTS

3.1 Key Factors and Relationships

Having examined the variables relevant to estimating the amount of telecommuting occurring on any single day, we turn now to those factors necessary for estimating the transportation impacts of telecommuting. The average transportation impacts for any one occasion can be multiplied by the expected number of occasions (O) to obtain the (estimated) aggregate impacts, which can be expressed either on a per-weekday basis, or as a proportion of total travel. Here, we focus on vehicle-miles traveled (VMT) as a key travel indicator of interest, but a similar approach may be taken with other indicators such as number of trips, peak period trips or VMT, person-miles traveled, and so on. To analyze the travel impacts for a single occasion, the key questions are: how far does the average telecommuter commute? How much of that is actually eliminated due to telecommuting? What proportion of total travel does that represent? And what about increases in travel that might occur, due to changes in residential location, increases in non-work travel, mode shifts, latent demand, and induced demand?

Specifically, let

D = the average round-trip commute distance in drive-alone vehicle-miles of those telecommuting on a given day,

α = the proportion of telecommuting occasions that eliminate a vehicle commute trip,

M_1 = the average total drive-alone VMT **by** a telecommuter on an ordinary (non-telecommuting) weekday,

M_2 = the average total drive-alone VMT by any worker on an ordinary weekday,

M_3 = the average total (drive-alone and rideshare) VMT per licensed driver in a calendar week, and

P = the population of licensed drivers.

Then αD is the average number of vehicle-miles eliminated per telecommuting occasion, and it is useful to define the key quantity

$V = O \times \alpha D$, the total expected number of vehicle-miles eliminated on any given weekday.

As mentioned earlier, for some applications it is the absolute reduction αD or V that is important. It is also valuable, however, to express the reduction in terms of proportions of some total amount of travel. Three such totals are of interest, defined as M_1, M_2, and M_3 above. The first measure allows us to express αD as a proportion of telecommuters' own total travel, and the latter two allow us to express V as a proportion of travel by everyone. Specifically, we can compute:

$\alpha D / M_1$ = the average proportion reduction in VMT for a telecommuter on a telecommuting day,

$\alpha D \times 5 \times F$ = the average number of vehicle-miles eliminated per telecommuter in a five-day workweek,

$\alpha D \times 5 \times F / 5 \times M_1 = \alpha D \times F / M_1$

= the average proportion reduction in VMT for a telecommuter over a workweek,

$O \times \alpha D / E \times M_2 =$ the average proportion reduction in workers' total weekday VMT,

$O \times \alpha D \times 5 = V \times 5 =$ the average total vehicle-miles eliminated in a five-day workweek, and

$X = O \times \alpha D \times 5 / P \times M_3 =$ the average proportion reduction in total household VMT.

To account for hypothesized increases in travel; let

N, R
= the expected increases in travel due to non-work trip generation and longer commute distances due to residential relocation, respectively, expressed in terms of fractions of the reduction in VMT (V), and

L, I
= the expected increases in travel due to the additional effects of latent demand and induced demand, respectively, expressed as fractions of the reduction in VMT.

Then the net change in VMT will be equal to

$V - (N+R+L+I) \times V.$

If N+R+L+I exceeds one, then the cumulative generation effects exceed the substitution effects and the net result will be increased travel.

As with the adoption of telecommuting, what is known about each of the factors listed above is discussed in the remaining subsections of this 'section. We continue the running example by proposing an illustrative value for each factor and discussing the combined outcome in the final subsection.

3.2 How Far?

In this subsection we estimate the reduction in VMT due to the elimination of the commute trip by telecommuting. We focus on drive-alone vehicle-miles rather than on person-miles since that is the critical measure as far as congestion and air quality are concerned. Eliminating a person-trip taken by bus or walking (or even a carpool trip if the carp001 vehicle still makes the commute) does not by itself affect either congestion or air quality.

As a simplification, we assume that when the conventional commute trip is not made, the full round-trip distance (in drive-alone vehicle-miles) between the telecommuting location and the regular workplace is not traveled. This will slightly overstate the'reduction, since in some cases trips that were chained to the commute will still take place. However, this can be compensated for by adjusting the factor N appropriately (see Section 3.4.1).

3.2.1 *The Value of* α

On the other hand, we do *not* adopt the simplification, as is often done in a "quick-and-dirty" estimate of travel reduction due to telecommuting, that every telecommute occasion eliminates a conventional commute trip (corresponding to $\alpha=1$). Mokhtarian (1997) points out that in one sample of 34 telecommuters, close inspection of the circumstances revealed that for five (15%) of those people, commute trips were not being eliminated. "For three of those participants – maternity and temporary disability cases – the alternative to working from home was not working at all. For a fourth, the alternative was continuing to work part-time (three days a week only, all in the main office, instead of three days in the office and the other two at home). The fifth respondent telecommuted partial days, which shifted commute travel out of the peak but did not eliminate it."

At least three other studies examined this issue. In analyzing a sample of 3,646 center-based telecommuting occasions, Mokhtarian, ***et al.*** (1996a) found that trips to the regular workplace were made on 8% of those occasions. For home-based telecommuting, Henderson, *et al.* (1996) reported that 10 (14%) out of 71 home-based telecommuters in their sample made drive-alone commute trips on telecommuting days. Koenig, ***et al.*** (1996) reported that three (7.5%) out of 40 telecommuters in their sample did the same, although this only accounted for 6% of the telecommuting person-days in the sample. Both of these latter sources also pointed out that not *every conventional* workday involved a drive-alone commute. Nationwide, for example, 73.2% of commute trips in 1990 were drive-alone (Ball, 1994). Drive-alone mode shares for telecommuters in these two studies were higher, in the 81-83% range.

Thus, unless the proportion of telecommuting occasions is discounted by the share of those occasions which would not have involved a drive-alone commute and the share on which the commute is actually made, the effects of telecommuting on traffic and air quality will be exaggerated. To see the combined impact of these two possibilities, consider 100 telecommuting occasions. On only 82 (say) of them would the telecommuter have commuted by driving alone, so at most 82 commute round trips would be eliminated. But on perhaps 10 of those 100 occasions (taking the midpoint of the 6-14% range found in the literature), the telecommuter actually makes a drive-alone commute after all, meaning that only 72 round trips are eliminated. Thus, we take 0.72 as our illustrative value of a. That is, we estimate that telecommuting actually eliminates a commute vehicle-trip only 72% of the time.

3.2.2 *The Value of D*

The second factor in assessing the quantity of vehicle-miles eliminated due to telecommuting is the average round-trip (drive alone) commute distance, D. For our hypothetical example, we offer a high estimate of D representing current conditions, and a low estimate of D representing hypothetical future conditions. The high estimate of D is based on average distances observed for telecommuters to date. For example, Mokhtarian, *et al.* (1995) take the weighted average of drive-alone commute distances for telecommuters in five studies and obtain a 26.3-mile round-trip distance. In the four more recent-studies summarized in Table 2, average commute VMT savings ranging from 29 to 41 miles were found, with a weighted average of 34 miles per telecommuting occasion.

TABLE 2
SUMMARY OF TRANSPORTATION FINDINGS FROM PREVIOUS STUDIES [1]

	Puget Sound[2]	State of California[3]	Puget Sound Telecenter[4]	Neighborhood Telecenters[5]
Dates of Study	1990-91	1988-90	1990-91	1993-95
Type of Telecommuting	home+center	home	center	center
Sample Size (Telecommuters)	72	40	8	24
Sample Person-Days				
Non-t'cing (NTC) Day	251	114	28	39
Telecommuting (TC) Day	108	52	13	30
Sample Total Trips				
NTC Day	948	429	95	88
TC Day	279	142	53	96
Per Person-Day Averages (Drive-Alone Mode):				
Vehicle-Miles				
NTC Day	52	45	‘63	59
TC Day	19	10	29	21
Difference (TC - NTC)	-33	-35	-34	-38
Percent Change	-63%	-77%	-54%	-65%
Vehicle-Trips				
NTC Day	3.7	3.8	3.4	2.3
TC Day	2.6	2.7	4.1	3.2
Difference (TC - NTC)	-1.1	-1.0	+0.7	+0.9
Percent Change	-30%	-27%	+20%	+42%
Change in Commute VMT	-35	-29	-32	-41
Change in Non-Commute VMT	+2	-5	-2	+3
Change in Commute Trips	-1.4	-1.5	+0.5	not avail.
Change in Non-Commute Trips	+0.3	+0.5	+0.2	not avail.

Notes to Table 2:

1 All four studies are based on travel diary data collected before and after telecommuting began.

2 Source: Henderson, et *al.* (1996).

3 Source: Koenig, *et al.* (1996).

4 Source: Henderson and Mokhtarian (1996).

5 Sources: Balepur, *et al.* (1996) or Mokhtarian, *et al.* (1996a).

In the former group of studies, each telecommuter was given equal weight. In the latter group of studies, the actual savings for a specific person was weighted by the number of telecommuting occasions for that person. It is plausible for there to be a relationship between commute distance and telecommuting frequency (the longer the commute distance, the greater the motivation to telecommute more often), although several previous studies have notably failed to find such a correlation (Olszewski and Mokhtarian, 1994; Mannering and Mokhtarian, 1995; Mokhtarian, 1997). Sullivan, *et al.* 1993, however, did find commute time significant in the preference for full-time telecommuting. Nevertheless, if such a relationship does exist, the latter estimate of commute VMT savings per telecommuting occasion is preferable because it accounts for that interaction (the commute reduction for more frequent telecommuters is counted more often in the average). However, it is important to realize that the number 34 represents not just D but αD, since it is averaging out distances traveled over all person-days in the sample (thus taking into account regular days on which commuting did not occur and telecommuting days on which commuting did occur). Dividing 34 by $\alpha=0.72$ would give an estimate of $D=47$ vehicle-miles reduction on a telecommuting occasion.

On the other hand, it is clear from the above discussion, as has been noted before (Mokhtarian, *et al.*, 1995), that the early adopters of telecommuting measured in all of these studies tend to have longer-than-average commutes. It does seem to be the case that longer-distance commuters are more motivated to adopt telecommuting: commute characteristics generally turn up significant in models of telecommuting preference and choice (Mokhtarian and Salomon, 1997, 1996b; Bernardino and Ben-Akiva, 1996; Bagley and Mokhtarian, forthcoming), even though as noted above they do not always seem to affect choice of telecommuting frequency. However, the same models identify numerous other variables significant to the adoption of telecommuting, and hence it would be expected (and is in fact observed) that people even with relatively short commutes find telecommuting attractive for other reasons. The observed commute length averages for these telecommuters may be due in part to a bias in the programs studied toward telecommuting as a transportation mitigation strategy. In some cases a long commute was actually an explicit selection criterion for participants.

Hence, it is reasonable to believe that in terms of commute length, the relatively small proportion of telecommuters measured in these several studies are not even representative of all current telecommuters, let alone of telecommuters in the future. Nevertheless, to illustrate an extreme, we will take $D=47$ as our high (current) estimate.

Over time we should expect the commute lengths of telecommuters to decrease, and perhaps to approach the average for all workers, although the average for telecommuters will probably remain somewhat higher (Mokhtarian, et *al.*, 1995). Hence, the low (future) estimate of D is based on average population commute lengths Accordingto the Nationwide, Personal Transportation Survey (NPTS) (Hu and Young, 1992), the average (one-way) commute length in 1990 was 11 .O vehicle-miles. Arbitrarily supposing that length to rise to 15 miles (at least for telecommuters) by some future date, and dividing that by an average vehicle occupancy of 1.1 gives an average of 13.6 drive-alone miles. We take D=27 as our low estimate of round-trip vehicle-miles reduced on a telecommuting occasion.

As a side note, we have not in this paper dwelled on the distinction between home-based and center-based telecommuting. Table 2 illustrates that even though center-based telecommuters tend to travel farther on telecommuting days than their home-based counterparts (primarily due to making the commute trip to the telecenter), they also tend, to travel about the same amount farther on their non-telecommuting days, with the net reduction in vehicle-miles being approximately equal for both groups; However, differences in adoption'and impactsbetween home- and center-based telecommuting are important areas for future research.

3.2.3 The Value of V

As indicated earlier, the total number of vehicle-miles-eliminated due to telecommuting on a single workday (V) is equal to the number of telecommuting occasions on that day (0) times the average number of'miles saved per occasion (αD). The current base case estimate, of V is given by using the low value for 0 and the high value for D; that is,

$V = O\times\alpha D = 14{,}592\times0.72\times47 =$ 493,793 miles per weekday, or (dividing by E).about !&mile per worker per weekday.

To estimate the value of V in the future, we should use the high value for 0 and the low, value for D. That is, in the future, more workers are likely' to be able to telecommute, but their average commute lengths are likely to be shorter and, hence the per-capita reductions due to telecommuting likely to be lower. Multiplying the illustrative values out gives

$V = 27{,}360\times0.72\times27 =$ 53 1,878 miles per weekday.

Note that V increased by only 8% even though 0, the number of telecommuting occasions, increased by 88%. While there is obviously a certain degree of arbitrariness in the choices for the high values of A and the low values 'of D, the point is not the specific number arrived at here for a future value of V, but rather to illustrate' that counteracting forces may well result in the travel impacts of telecommuting increasing much more slowly than the adoption of telecommuting itself. In fact in the short term it is possible for the travel impacts of telecommuting actually to decrease in the-aggregate.

3.3 **Out of How Much?**

Is a daily reduction of half a mile per worker a lot or a little? To put the absolute reductions αD and V in context, we would like to- know what proportion of total travel they constitute. As defined in Section 3.1, we examine three measures of total travel, M,, M,, and M_3, to calculate four proportions.

3.3.1 *The Value of M_1*

For a base case estimate of M,, the total VMT per telecommuter on a non-telecommuting weekday, we take an average (weighted by the number of telecommuters in each study) of the "Vehicle-Miles, NTC Day" figures in Table 2 and obtain M_1=52. Since, as has been noted before, the telecommuters in these studies are. long-distance commuters, their total weekday drive-alone VMT is likely to be higher than the current population average, and higher than the average for future teleconimuters. For a future estimate of M,, we take the future value of M_2 (the population average weekday drive-alone VMT, estimated in Section 3.3.2 to be 33 miles), judgmentally increase that figure slightly 'to account for still-slightly-longer-than-average commute lengths of future telecommuters, and choose M, (future) = 37.

Using these two measures of M,, we compute αD / M,, the average proportion reduction in VMT for a telecommuter on a telecommuting day, to be 0.65 for the base case and 0.53 in the future. This illustrates that the savings in commute travel due to telecommuting is likely'to be a declining share of telecommuters' total weekday travel; as their commute distances approach the population average.

The measure αD / M, is commonly reported in studies of the impacts of telecommuting. on travel (note the "Vehicle-Miles, Percent Change" row of Table 2, with'reductions ranging from 54-77% and a weighted average of 67%; these numbers are consistent with the 66% reduction in car travel found in an Australian study: RTA, 1995), because it is readily available and requires no data external to the study. Although valid on its own terms,, it can be easily misinterpreted as suggesting highly exaggerated effects of telecommuting (Mokhtarian, 1996). One deficiency of this measure is that it does not indicate the frequency with which 'such a reduction in VMT occurs. That deficiency is addressed by the second measure, which averages out the reduction on any one telecommuting day across the entire workweek based on the frequency with which telecommuting occurs.

Specifically, we compute $\alpha D \times F$ / M_1, the average proportion reduction in VMT for a telecommuter over a workweek. Taking F=0.24 as a constant, we obtain 0.16 for the base case and 0.13 in the future. That is, taking the frequency of telecommuting into account, the VMT reduction due to telecommuting is currently perhaps 16% of a telecommuter's total weekday travel (Balepur, et *al.* 1996), in process, found the reduction in their telecenter. study to be 17%, using the more accurate method of weighting *each individual's* VMT by the frequency of telecommuting for that individual, compared to a reduction of 12% obtained by multiplying averages in the aggregate as we have done here. Thus, the reminder is again in order that failing to account for interactions among variables may alter the results appreciably. In this case, it appears that there *is* in fact an interaction between telecommuting frequency and VMT).

3.3.2 *The Value of M_2*

These relative measures of reduction as a proportion of telecommuters' own travel are useful, but from a system standpoint it is more important to place the reduction in a broader context. Two measures for doing that are introduced: the first looking at workers' total weekday drive-alone travel and the second looking at all household vehicle travel. The first measure is useful from the perspective of the impact of telecommuting on weekday congestion (although from that perspective it is incomplete-it should really include all weekday vehicle travel for the entire population, but values for that are less readily available); and the second is useful from the perspective of its impact on total fuel consumption for personal travel.

First, then, we estimate M_2, the average total weekday drive-alone miles per worker. For the base case, one way to do that is to take the weighted average for the, non-telecommuting control group workers reported by the studies cited in Table 2, which is 33 miles (the averages for each study are not shown in the table, but are either.32 or 33 miles in each case). However, these studies suggest that even the control group members have commutes and VMT that are longer-than-average although not as long as the telecommuters'. This is plausible since in many cases control group members are "telecommuter wanna-bes" who hope to join a later cohort of telecommuters (JALA, 1990). One clear lower bound for M_2 is the value for $M_3/7$, which is below taken to be 27 'for the base case. Hence, for the base case here, we judgmentally take $M_2=30$. For a future case we will arbitrarily consider a 10% increase in total weekday drive-alone VMT, and take $M_2=33$.

Then We have $O\times\alpha D / E\times M_2$ = 0.493793 / 30 = 0.016 for the base case, and 0.53 1878 / 33 = 0.016 for the future case. That is, the reduction in VMT due to telecommuting represents 1.6% of workers' total weekday drive-alone VMT under both cases, with future increases in the number of telecommuting occasions being counterbalanced by decreases in average-(absolute) reductions per occasion and slightly higher background amounts of travel.

3.3.3 The Values of M_3 and P

Finally, it is in some contexts most germane, to examine the reduction in VMT as a proportion of total household personal vehicle travel, including travel by non-workers and weekend travel. Thus, we take a seven-day week as the unit, with $O\times\alpha D\times5 = V\times5$ being the average total vehicle-miles eliminated in a week (assuming that telecommuting eliminates commuting only during the five-day. workweek). We need values for P, the population of licensed drivers (expressed in terms of E), and M,, the average total household VMT per driver in. a week.

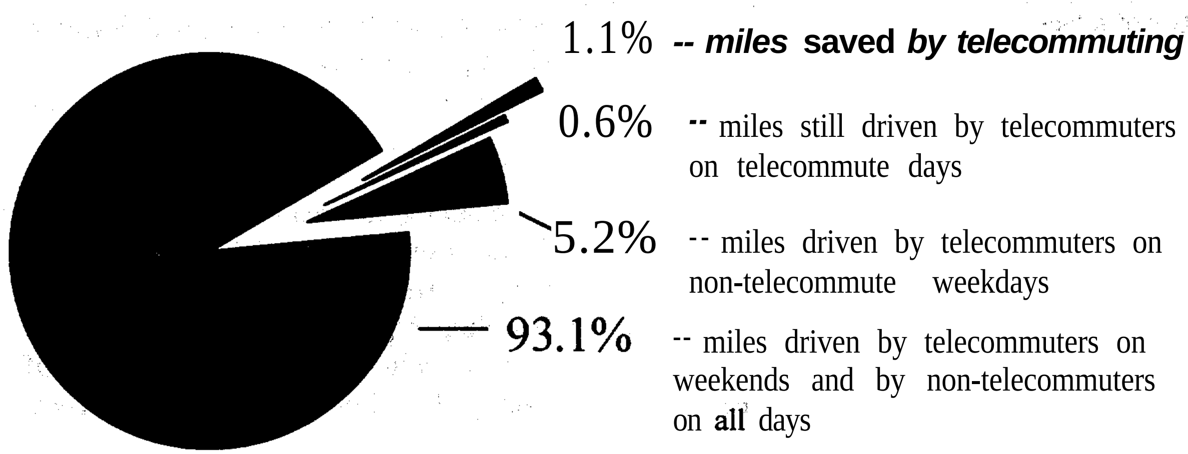
For P, we estimate the number of licensed drivers in the US in 1990 at 143,3 12,000 based on the NPTS (Hu and Young, 1992), take the number of (civilian) workers in the same year to be 117,914,000 from *The Statistical Abstract of the United Stares,* and computing the ratio of those two numbers to be 1.22, use $P=1.22\times E$ (that is, 1.22 licensed drivers per worker).

For the base case for M_3, we estimate the number of licensed drivers per household in the US in 1990 to be 1.54 based on the NPTS, find the average annual VMT per household to be

15,100 miles from the same source, and from those two numbers compute 9,805 annual miles or 27 daily miles per driver, for a weekly total of M_3 = 7x27 = 189. For the future case, we again assume a 10% increase in total household personal vehicle VMT, giving M_3 (future) = 208.

From these assumptions it can be calculated that X, the average proportion reduction in total is equal to 0.011 for the base case and 0.010 for the future case. That is, as shown in Figure 2 for the base case, direct reductions in VMT currently constitute about 1.1% of total household vehicle travel (at most – recall that base case estimates of A, perhaps W, and particularly D are considered to be on the high side), and are likely to stay in that range for some time to come. These values fall in the range (0.7 - 1.4%) projected by a US Department of Transportation study for the year 2002 (US DOT, 1993), although those results were based on different assumptions notably, a lower proportion of telecommuters, saving fewer miles on average per occasion, but telecommuting far more frequently).

Figure 2: Travel savings due to telecommuting (base case) ,



3.4 What about Increases in Travel?

There has been speculation for some time (e.g. Albertson, 1977;. Salomon, 1985; Mokhtarian, 1990) about the extent to which the savings in travel due to the elimination (or reduction) of the commute might be counteracted by increases in travel. Travel could be stimulated in several ways, representing N, R, L, and I, respectively:

- The time saved by telecommuting may partially be spent in out-of-home activities generating new travel.

- The ability to commute less often might prompt some to move farther away from work -potentially far enough that total commute VMT even on a smaller number of commuting days exceeds previous levels.

- Any transportation capacity freed up by large numbers of people telecommuting will be partially or completely filled by the realization of latent demand on the part of others. Hence, travel saved by telecommuters may be compensated for through travel increases by non-telecommuters.

- Telecommunications may directly stimulate newtravel (for telecommuters and non-telecommuters alike) through increasing both contacts with other people and information about activities of interest.

Note that new non-work travel may also be viewed as a form of induced demand, but in the present context we conceptually distinguish N from I by the characteristic that new non-work travel is a direct consequence of the time saved by telecommuting itself (and hence applies only to telecommuters and perhaps their household members), whereas "I" here refers to travel generated by other telecommunications applications, which can occur for non-telecommuters as well. In practice, however, it can be difficult to distinguish these two effects, at least for telecommuters.

Another way in which telecommuting has been hypothesized to increase travel is through shifts away from shared modes of transportation in favor of driving alone, resulting in relative increases in VMT even if person-miles traveled remain constant' or decline (see, e.g., Mokhtarian, 199 1 b). These effects, however, will be automatically captured through measured differences in a and N, which account for daily differences in vehicle-miles for commute and non-commute trips due to telecommuting.

The four potential effects listed above are discussed in turn. Particularly the last three types of effects are longer-term and indirect, and hence they have been much less studied than the other factors analyzed so far. For R, L, and I, then, the numbers chosen for the illustrative example become somewhat more speculative.

3.4.1 Non-work Travel

The studies summarized in Table 2 partition the total VMT on telecommuting and non-telecommuting days into commute and non-commute, so that it is possible to examine separately the changes in each type of travel. From Table 2 it can be seen that (as expected) commute VMT decreased in every study. Non-commute VMT, on the other hand, decreased slightly in two of the studies and increased slightly in the other two. For at least the studies in the last two columns of the table, the changes in non-commute VMT were not significant; statistical tests were not reported for the first two studies. Hence, it might be interpreted that the observed changes simply constitute random fluctuations around a base of essentially no change. In fact the weighted average change in non-commute VMT across all four studies is precisely 0, and thus for the base case we take N=0.

This is a plausible result: telecommuters are, presumably, working at least their normal hours (and thus not making new trips during that time), and there is anecdotal evidence that many of them work through most or all of what would otherwise be their commuting time as well. New trips that are made during those times may be walk or bike trips. Mokhtarian, et *al.* (1995) present several other explanations for the observed result. In particular, they point out that since these tend to be long-distance commuters, they may already be traveling more than they would like on their regular commuting days, and be more than happy to curtail their travel when telecommuting makes it possible. In the Puget Sound study, for example (Henderson, et *al.*, 1996), no drive-alone trips at all were made on 38% of all telecommuting days, compared to 9% of all non-telecommuting days (for both telecommuters and controls).

This suggests, however, that as average commute distances for telecommuters become shorter over time, this result may change, and the hypothesized desire for mobility (Salomon, 1985) may lead to a discernible increase in non-commute travel on telecommuting days. To adopt a reasonable but conservative future value of N (and in keeping with the adage that "the future is already here; it's just not evenly distributed yet"), we use the highest proportionate increase in non-commute VMT observed to date, namely the 3 miles found in the Neighborhood Telecenters study (compared to a commute decrease of 41 miles), and take N (future) = 3/41 = 0.073. That is, in the future, increases in non-commute travel might counteract 7% of the decrease in commute travel.

3.4.2 Residential Relocation

Researchers have speculated for some time about the decentralizing effects on urban form of telecommuting and other telecommunications applications, but scant empirical evidence is available to date. The meager direct evidence that is available (Nilles, 1991) shows little or no impact on residential relocation, but those findings are based on self-reports from short-term experience with telecormnuting, during which time frame large numbers of relocation decisions could not be expected to occur.

At least one theoretical model of residential relocation due to telecommuting has been advanced from which it is possible to estimate tentative values for R (Stough and Paelinck, 1996, also model the impact of telecommunications on residential choice, but since their choice alternatives are location categories-central city, suburb, edge city-it is not straightforward to express the changes. forecast by their model in terms of changes in VMT). Lund and Mokhtarian (1994) propose a simple location model for a monocentric metropolis. Briefly, to roughly estimate the impact of residential relocation on the travel saved by telecommuting, we insert representative values from the example developed here into their equations: In their notation, we take for the base case T_0 = 470, T, = 357, k = 0.2, and $d_0^* = \alpha D/2$ = 17, where T_0 and T_1 are the number of one-way commute trips per-year before and after the onset of telecommuting (so that T, / T_0 = 1 - F in our notation), k is the decay constant of land prices (smaller values of k indicating a shallow decline in prices as one moves away from the, city center), and d_0^* is the one-way number of vehicle-miles traveled on each commute.

With these values, we. find the number of miles saved annually by telecommuting *in the absence of residential relocation* to be $d_0^* \times (T_1$ - T,) = 192 1, the change in d_0^* *with residential relocation* to be $\ln(T_0$ / T,) / k = 1.37 (translating to a change in one-way commute length of 1.37 / a = 1.85), and the increase in miles traveled due to relocation to be $1.37 \times T_1$ = 490. Then the ratio 490/1921 = 0.26 represents the proportion of miles saved that are offset by residential relocation, and may be taken as an estimate of R. Similar calculations for the future case, in which the only change is d_0^* = 10.0, leads to R (future) = 0.43.

That is, under classical location theory, telecommuting at 24% frequency prompts an individual to move 1.85 miles farther from work, resulting in 1.37×2 additional vehicle-miles being traveled. on each of the 76% of workdays on which a conventional commute is made, resulting in an increase in travel which constitutes 26% of the savings in the base case, and 43% in the future (for which the same absolute increase in travel is divided by a lower savings due to the assumption that average commute distances for telecommuters decline over time in the aggregate).

Several comments are in order. First, interrelationships among variables should again be emphasized. In particular, in Lund and Mokhtarian's model the assumed increase in commute distance due to residential relocation is very much a (non-linear) function of .telecommuting frequency: the more often one telecommutes, the farther away is the optimal residential location *but* the less often that greater distance is traveled, The -outcome is that the more frequently telecommuting occurs, the closer the net travel impact (taking residential relocation into account) is to the direct impact in the absence of relocation, i.e. the smaller R is. This may be the reason why another study (US DOE,. 1994) estimated the increase in travel due to "increased urban sprawl" at roughly 16% of the savings in travel (that study focused on fuel consumption rather than VMT) -- it assumed average' telecommuting -frequencies around 60%.

At another level, however, we must question how accurately such a simple relocation model will reflect actual behavior, especially in view of -the widespread recognition of the limitations of such models (see, e.g., Giuliano, t989). Even aside from the question of the extent to which commuting costs any longer influence location decisions, a change of 1.85 miles in the theoretically optimum location is not necessarily likely to prompt a move in view of the transaction costs of such an action. Further, the question of the duration of telecommuting, as discussed in Section 2.6, should be taken into account: a telecommuting spell of only one or two years is also not likely to prompt a move.

In summary, then, this author finds it difficult to believe that the part-time, short-term telecommuting that seems to be the norm in most cases is *itself* going to stimulate a great deal of residential relocation (decentralization is likely to continue to occur for a number of other reasons, but that is not the subject here). These observations are somewhat corroborated by the aggregate empirical evidence offered by Kumar (1990), in which he shows using NPTS data that commute distances are in fact *decreasing* over time for information workers, and *increasing for* blue-collar workers. This is happening even while commute frequencies decline for information workers (a fact which Kumar attributes to a combination of telecommuting and "flexible work arrangements" without being able to distinguish the relative proportions of each).

Hence, the calculated values of R (0.26 now and 0.43 in the future) do not appear to be realistic, and on the basis of the available empirical evidence, there does not appear to be any justification for choosing any particular value of $R > 0$. Accordingly, we take R=O until new evidence presents itself. However, this effect should be monitored empirically, as it may be the case that future adopters who have shorter commutes when they begin telecommuting than do today's adopters, may be more likely to relocate.

3.4.3 Latent Demand

The ability of new transportation capacity to attract new trips has been recognized (see, e.g., Shunk, 1991; Transportation Research Board, 1996) but the behavioral mechanisms involved are poorly understood. The process is a complex one, in which realized latent demand on a capacity-improved link may reflect some combination of:

- *development* traffic due to land use changes;
- natural *growth* due to demographic changes;
- traffic ***diverted*** from other routes;
- traffic *transferred* from other modes;
- traffic *shifted* to new destinations; and
- new trips *induced* by the newly-available capacity

(Zimmerman, *et al.*, 1974, cited in Kitamura, 1991). At a systemwide level, some of these effects result in only a redistribution of, rather than an increase in, total travel.

Apparently only one study (US DOE, 1994) has attempted to quantify the effect of the realization of latent demand on filling up the system capacity freed by telecommuting. That study estimated that latent demand would offset 50% of the direct savings in travel. The assumptions made there differ from ours in ways similar to those for the US DOT study cited above, but, as above, those differences counteract each other to result in similar projected savings in travel. Hence, there is no apparent reason for modifying the DOE result, and again until further evidence is developed we take $L = 0.50$. However, that study also notes that the latent demand effect is unlikely to occur in areas in which congestion is not a problem. There may also be a threshold effect; that is, very small (and unpublicized) increases in effective capacity may not be sufficient to bring out latent demand. In that case, the systemwide levels of travel reduction due to telecommuting seen today (and even into the future if the analysis presented in this paper is to be believed) may not be sufficient to trigger this effect.

3.4.4 induced Demand

If little is known about the impacts of latent demand, even less is known about the demand for travel induced by telecommunications capabilities themselves. One report (Niles, 1994) provides a thoughtful extended discussion of ways in which this phenomenon might occur, including:

- an increased awareness of activities of interest;
- stimulation of economic growth, which stimulates travel;
- an expanding network of personal and business relationships;
- geographic decentralization (partially represented here as the "R" effect);
- an increased customization and rapid-response- capability;
- reducing the disutility of travel by making travel time more productive; and
- improving the efficiency of the. transportationsystem.

However, the report stops short of quantifying the impacts of all these processes, and in fact no one has attempted to do so to this author's knowledge. Not wishing to rush in where angels fear to tread, this author will refrain from doing so as well.

It can be pointed out, however, that all of the travel generation effects discussed in Section 3 .4 collectively manifest themselves in increased total VMT on non-telecommuting days (for telecommuters and non-telecommuters alike). So one (artificial) way of accounting for all these effects simultaneously is simply to adjust an assumed. growth rate in VMT to represent various future scenarios of increased travel. Time-series or other models can be calibrated to forecast increases in VMT, and refined over time as more information on the causal processes involved becomes available.

It should also be pointed out that if a model of induced demand does become available, care should be taken when fitting it into the current framework that N, R, and L effects are not double-counted.

3.5 Combined Outcome

The final two rows of Table 1 present the "bottom line" impacts of telecommuting using, the illustrative case discussed, here (and taking I = 0). N+R+L+I = 0.50 for the base case, and 0.57 for the future case, meaning that the net reduction in travel is only at most about. 50% and 43%, respectively, of what would be assumed if stimulation effects were not taken into account (a non-zero assumption for I would reduce those numbers still more). These two, values have the intriguing result that the net absolute reduction in VMT is higher for the base case (nearly 247,000 miles) than for the future case (about 229,000 miles) - in either case, about 0.2 miles per worker.- As can be seen, the outcomes of the two cases are so close that small changes in the assumptions either way' can alter the relative ordering of the results. For example; had we assumed N to be equal for both the base and future cases, the ordering of the two. outcomes would have been reversed. Nevertheless, it is not unreasonable to expect the. trip *generation effects of telecommuting to increase over time to the extentthat the net reduction in travel shrinks. In fact, had we taken R=0.43 in the future case as the Lund and Mokhtarian model suggested, then N+R+L+I would exceed one (the more so to the extent that $I > 0$), meaning that in the future, the travel stimulation effect of teiecommuting would equal or exceed its travel reduction effect.

4. IMPLICATIONS AND DIRECTIONS FOR FUTURE RESEARCH

This paper has attempted to synthesize (combine) what is known about the adoption and travel impacts of telecommuting into a synthetic (artificial) multiplicative model containing the key relevant factors. Plausible assumptions (based on the best available empirical evidence) about the value of each factor result in estimates of relatively modest transportation savings—probably currently no more than 0.6% of total household travel, as shown in the last row of Table 1. Even more importantly, it appears to be likely that, due to counteracting forces, the aggregate travel impacts will remain relatively flat well into the future (potentially even declining), even if the amount of telecommuting increases considerably. Since it was asserted in the introduction to this paper that telecommuting probably has the highest potential for travel reduction of any of the tele-applications, the outlook for telecommunications as a major solution to urban congestion is not promising.

Thus, in response to the potential concerns of regional planning agencies, it appears quite unlikely that telecommuting will reduce travel to the extent of obviating the need for new infrastructure capacity (whether that capacity should be provided, and the particular modal form it should take, however, are separate questions to which the current paper does not speak). On the other hand, the potential reductions in travel due to telecommuting are of an order of magnitude comparable to the estimated impacts of other transportation demand management (TDM) strategies. A bundle of such TDM measures that includes telecommuting may collectively have a noticeable impact on congestion. For that reason, it continues to be desirable to promote telecommuting as a TDM strategy (with appropriate expectations as to its effectiveness), and to learn more about its impacts on travel.

A great deal of uncertainty remains, both in the likely future values of the key factors studied here and in the way those factors will combine to give an aggregate result-enough uncertainty to warrant further refinement of our knowledge in this area. For example, until recently, most telecommuting was voluntary-chosen by the employee with the concurrence of management. Now, thousands of employees (so far, typically sales workers) in firms including Ernst and Young, IBM, AT&T, Xerox are being involuntarily shifted to "non-territorial office" arrangements as a cost-saving strategy on the part of the organization (see, e.g., Shellenbarger, 1994). Trends in the adoption of this form of telecommuting should be monitored and its travel impacts assessed.

The results presented here may differ somewhat if a transportation indicator other than VMT is chosen as the focus. For example, adoption of partial-day telecommuting may be, increasing faster than full-day telecommuting. That is, it may be increasingly common for professional workers to work at home an hour or two in the morning to avoid rush-hour traffic, so that if peak-period trips were the measure of interest, the impacts of telecommuting may be somewhat more substantial. However, it is also likely that many of those workers would not apply, the label "telecommuting" to what they are doing, which. highlights the need for careful question wording in any attempts to survey the extent of such practices.

Discussion of each factor and relationships among them has identified-a number of areas needing further research. For example, it would be valuable to gather data on A, W, and C (those who can, want to, and do telecommute) from a larger 'and representative sample (and on an ongoing, say annual, basis), to analyze the interactions among those dimensions and trends in their values. It is important to further develop causal models of telecommuting frequency. The longitudinalstudy of temporal patterns and duration of telecommuting is a critical missing link to date, with duration of telecommuting potentially affecting downstream factors such as residential relocation decisions. Little is. known so far 'about. the adoption , of center-based teleconunuting and potential differences in travel impacts from the home-based form. And, of course, the-entire set of processes by which travel can be stimulated through telecommunications deserves careful analysis.

These studies would improve our ability to forecast, each factor of the simple multiplicative model presented here: Additional work could be done to further refine the model itself. Rather than using only anaggregate expected value for each. factor as has been done here, distributions for each factor Can be developed., In. some cases these can be joint distributions among two or more variables to account, for key correlations; in some cases-(as has been done by Mokhtarian and Salomon and others for the variables W and C) a variable can be represented through a disaggregate probabilistic submodel as a function of other explanatory variables. Then a:population outcome can be estimated through a Monte Carlo simulation, in which for each simulated individual, values from the assumed distributions or submodels. are generated and combined in the model at a disaggregate level, with the results summed across individuals; The model- could eventually incorporate a dynamic element, to account for changes over time in ability to telecommute, desire, to telecommute, frequency of telecommuting, commute length, total VMT, and so on. Such a dynamic+ disaggregatesimulation model seems to fit well with the current approach to improving travel demand forecasting models in general. (e.g. RDC, Inc., 1995), and could probably be-relatively easily integrated with that approach;

The illustrative future case numbers presented in Table 1 can be viewed as a plausible future scenario "letting nature take its course". Planners and policy-makers may wish to consider how those numbers might change in the presence of policies that aggressively" support telecommuting. For example, allowing congestion to reach far worse levels than are experienced today, or introducing serious congestion pricing mechanisms, would increase the salience of commute reduction as a personal motivation to telecommute. This would presumably increase W (the proportion of those able to telecommute who want to); C (the proportion of those who can and want to who do), and F (the frequency of 'telecommuting). which in the present formulation are assumed to remain constant over time. Regulatory mechanisms could diminish the organizational constraints on telecommuting and hence increase A (the proportion of the workforce that is able to telecommute) more rapidly than would be the case otherwise.

Further research is therefore needed to understand the likely impacts of such policy measures. Existing behavioral- models of telecommuting preference and choice (containing policy-sensitive variables) can be used as a starting point in evaluating such "what if' scenarios.

New stated preference models can be developed in the context of policy evaluations, and calibrated against the revealed preference or manifest behavior shown by current workers (see, e.g., Morikawa, 1994). When such policies are initially introduced on a limited basis, experiments and pilot studies should be conducted as early as possible and used to identify the actual impacts on telecommuting. In short, empirical information on the impacts of such policies should be gathered early and often, and the expectations for such policies should be revised as new information becomes available.

Finally, two additional important, phenomena falling under the broader rubric of "teleworking" which have not been emphasized here but whose transportation impacts need further study are. the increase in home-based businesses and in the number of mobile workers in the workforce (Handy and Mokhtarian, 1996b; US Congress Office of Technology Assessment, 1995). Mokhtarian and Henderson (1996) found that home-based business workers have higher daily total, work-related, and drive-alone trip rates than other workers, but have lower total travel time. Trip departure times for home-based workers were unimodally rather than bimodally distributed across the day, and considerable variations. were found across workers in different industries. These results illustrate that the travel patterns of home-based business workers differ substantially from conventional workers', and current regional travel forecasting models are not well-equipped to treat these patterns. Further, it., is an interesting research question to explore how operating a home-based business affects the choice of residential location (central city, suburban, exurban, satellite town, out of the region of employment altogether) and characteristics of the dwelling unit.

Similarly, the travel and communication patterns of mobile workers are likely to exhibit considerable variation, both within subcategories of mobile workers, and between them and non-mobile workers. For both mobile and home-based workers (which are not mutually-exclusive categories), the predominant effect of telecommunications is probably not to reduce travel, but to increase the flexibility of travel. Total travel may in fact be higher for these workers than for others, but shifted to off-peak periods where possible. When peak-period travel is necessary, telecommunications (the cellular phone) can reduce the cost of congestion for these workers. Additional research is needed to further understand the travel and communications patterns of teleworkers of all types.

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Incorporating the effects of telecommunications on metropolitan area vehicle movement could potentially include all of, the ways that physical movement patterns are changed'by the growing electro-optical movement of information over distance. Such patterns of physical movement include the number of trips, their timing, their origins and destinations and thus trip length, their routing over the road network, and the mode of travel. Specifically:

Trip volume: Telecommunications can be a substitute for a trip in the case of telecommuting, teleshopping, and telelearning. Or telecommunications can be the generator of trips, by creating a wider focus of attention that creates awareness of new places to visit and new people to meet, or by making travel time more productive. As described in *Beyond Telecommuting* (US DOE, 1994), the list of ways in which telecommunications increases trip-making is just as long as the list of ways in which it decreases trip-making.

Trip timing: Telecommunications can also cause trips to be made at different times, perhaps avoiding peak periods. Telecommuters and other home workers with flexible schedules have more opportunity to do some necessary errands during off-peak periods, and stay at home during the morning and evening rush. On the other hand, just-in-time delivery services like Federal Express, which are very much enabled by the technology and habits of the information age, generate vehicle traffic in evening rush hour in order to meet the deadlines that are part of their rapid service.

Trip Length: Telecommunications can change the length of trips, making them either longer or shorter. For example, an on-line information system could be designed to describe the nearest place to 'purchase a needed item, promoting purchase there rather than driving to a familiar place that is farther away. Telecommuting applications affect trip distribution, because of the long-run propensity of workers to choose residential locations based on the journey-to-work pattern. Consistent worker location data implicate telecommuting as a source of metropolitan sprawl, because people can now exercise residential preference without a long daily commute to a central office during peak traffic periods. The weekly trip to the supermarket, however, could -be a much longer trip for a person living in a rural region surrounding a metropolis. If the number of residents in an exurban region grows and a new grocery store locates there, then the daily commute for workers at that grocery store could be longer than average.

Trip routing: Telecommunications can furthermore cause the route of a trip to change. Good information about traffic conditions generated by Advanced Traveler Information Systems can be the motivation for staying off of a crowded corridor in peak, or driving into a crowded corridor that would typically be avoided'in the absence of an information system that can now reveal that the traffic is free-flowing.

Travel mode: Finally, telecommunications can cause the mode of travel to change. An information system that provides accurate, real-time information on the exact time when a bus will arrive at a nearby bus stop, or a system that enables buses to make front door pickups, could cause more people to ride the bus rather than use their private automobiles. Teleworking in the broadest sense, however, is likely to make mass transit and ridesharing relatively less appealing than private vehicle modes, because of the prospect of changes in economic structure, business processes, and land use in the direction of more temporary employment, just-in-time behavior; and geographic dispersion.

All of these aspects of telecommunications are considered in the sum of steps that make up the existing "four step" transportation model of Metropolitan Planning Organization (MPOs). As a quick review, the four steps of a transportation model, executed in this order, are:

Trip generation by trip type across each transportation analysis zone into which the metropolitan region is divided. The time-of-day of each trip generated, peak or off-peak, is included here as well.

Trip distribution that allocates all trips across and within the zones based upon origins and destinations of trips.

Mode choice that allocates trips across automobile, transit, and other modes.

Trip assignment that allocates all trips across specific freeways and arterials in the region's transportation network.

The remainder of this paper will focus simply on trip volume effects of telecommunications, primarily substitution, which is of public policy interest. In popular but somewhat inaccurate terms, this is the analogy of telecommunications acting as a mode of transportation. The story is a little more complex than this analogy implies, as we shall describe.

In consulting assignments for two MPOs, the Southern California Association of Governments and the Puget Sound Regional Council, Ellen Williams & Associates in association with Global Telematics took the approach of classifying by trip purpose that subset of telecommunications applications having an impact on physical movement. Such a classification is presented in tbetable below, which is an abridged version of Exhibit 11 in the ***Southern California Telecommunications Deployment Strategy,*** prepared by the Southern California Association of Governments in 1996.

Linking Trip Purposes to Telecommynicatious Applications

Travel destination	**Estimated relative share of daily trips**	**Telecom applications for trip saying**
Place of daily work	high	Telecommuting
Shopping malls	high	Teleshopping
Off-site work meetings	medium	All modes of teleconferencing
College campuses and high schools	medium	Networked electronic classrooms and libraries
Medical offtces	medium	Remote consultation, monitoring, treatment
Customers & prospects in the field (industrial & business sales)	low	Pre-visit qualification, electronic post-visit interaction, literature on line
Grocery stores	low	Electronic ordering and home delivery
Cinemas, video rentals, arcades	low	Enticing, in-home alternatives to'going out
Government buildings	low	Remote access to documents, services, hearings
Banks, financial services	low	ATMs, electronic transactions, loans by phone
Prospective employers, employment services	low	Electronic listings, video interviews
Houses for sale with listing agents	low	On-line photos, electronic signatures

As a first problematic comment on the list of applications in the table, we note that most MPOs model only a few, predominant trip types. At present, one of the two West Coast MPOs mentioned above models only commuting trips and shopping trips in their transportation planning, while the other MPO also includes school trips.

A next step in considering telecommunications effects on transportation is to assign mobility-influencing telecommunications applications into a framework that can be used in the overall transportation modeling process. Consultants' preliminary judgment on approaches for modeling telecommunications within the present four-step framework are as follows.

Approach One: Telecommunications Implicit in Present Model

The first approach assumes that many applications of telecommunications require no explicit consideration because the travel impacts of them are already incorporated into the transportation model via the MPO's existing periodic monitoring of travel characteristics. Telecommunications has been underway for many decades, and thus is built into today's travel patterns. If the MPO's baseline trip generation estimations are functions of travel volume influences such as numbers of people, households, workers, and vehicles per household, then telecommunications usage that either increases trips or decreases trips may be well reflected in changing coefficients in the equations that would show up over time as the equations are calibrated to the real world.

For example, consider the use of telecommunications as a substitute for meetings. Society is in the middle of a gradual evolution in the use of telecommunications as a way of meeting, an evolution that began with the growing use of telephones in the 1920s. Electronic mail came along later, and video conferencing more recently. These technologies are reaching use gradually and are fully encompassed in travel trend data that is used to create and calibrate present trip-generation models. When the model's trip generation equations are calibrated to actual trip generation measurements, the effect of many telecommunications applications is implicit in the changing coefficients applied to the demographic variables, in that same sense that economic growth and land use patterns are built in.

Another argument for claiming that telecommunications is implicit in the trip generation equations lies in the complex of ways in which telecommunications act on travel behavior. Considering just trip substitution, we can see at least five different mechanisms at work:

Equivalent functionality: The main method of trip elimination is that telecommunications lets people achieve enough of the functionality of going to a place without actually having to go there. Sufficient functionality is achieved from a distance by telecommunications allowing observation, transactions, communications, and information exchange. The use of telecommunications as a substitute for travel is called telesubstitution. Instead of driving to work, a worker stays home and telecommutes. Instead of registering for university classes on the campus, a student registers over the telephone.

Pre-travel verification: In addition to providing opportunities for telesubstitution, telecommunications also lets people call ahead to find out if the trip is or is not worth making. As a simple example, instead of driving around to a variety of stores looking for a particular item to purchase, a shopper phones to a number of stores until the item is located, and then drives to one store directly. This effect is closely related to telecommunications changing the length of trips.

Knowledge of travel conditions: Accurate, up-to-date-knowledge of conditions at the destination or on the journey can cause trips to be canceled as unnecessary with perhaps teleconferencing or other telesubstitution used instead of face-to-face presence., Joining the meeting by telephone is not so bad if the only freeway leading to the site of the meeting is blocked by an accident. This effect is closely related to the effect of telecommunication changing the timing or route of a trip, as discussed above.

Process reengineering: Going beyond decision making by individuals, telecommunications allows the revision of organizational operations to eliminate passenger and freight trips that raise costs unnecessarily. Instead of a soft drink delivery truck driving to a heavily used Coke machine once every two days to fill it up (whether needed or not), wireless radio status reporting on the contents of the machine allow the bottler to visit as needed, which results in visits that calculate out to one visit every 3.3 days.

Lifestyle patterns: Going beyond direct functional substitution, a fifth source of travel saving comes from telecommunications providing opportunities to change leisure, recreational, and personal activity toward patterns that generate fewer trips. An example here is members of a household more frequently staying home to surf the Internet rather than going out to see a movie at the cinema.

The modeling requirement for the out years is to estimate future changes in coefficients, perhaps based on past trends in the changing of those coefficients.

Approach Two: Overlay Outside the Model

A second approach to modeling telecommunications would be to include certain telecommunications applications in the modeling process through external processing outside of the flow of existing calculations in the model. Some telecommunications applications are not related to the existing variables in the modeling process. Other applications fall into this approach because the forecasting methodology is completely different from the one used in the regional transportation model. The Southern California Association of Government's present methodology of taking telecommuting and working at home as separate, outside, across-the-board overrides on the baseline trip generation stage of the model falls into this second approach. The caveat is that some applications of telecommunications can work to stimulate more trips as well as reduce trips. Given that the MPO's traffic model is aimed at summarizing all forces that bear on trip making, simply isolating the trip reduction side of telecommunications and applying it as an override on the trip generation baseline should be used with caution.

Approach Three: Explicit Incorporation Into the Model Steps

A third approach covers telecommunications applications that should be explicitly included in a particular appropriate step in the traffic forecasting process. This methodology would work where the application can be put into a transportation framework. Telecommunications applications incorporated under this approach must be assessed to determine which variable in the existing model represents their effect on travel. For example, occasional telecommuting from home might be incorporated as an additional mode in the modal choice step of the model. Some of the applications may affect more than one step in the modeling process, but most would affect the trip generation stage of modeling.

These three approaches are all ways of extending the traditional four stage transportation modeling approach to include the effect of telecommunications on all trip types. As the Travel Model Improvement Program goes forward, the daunting challenge will be to determine whether the structural effect of telecommunications causing trip replacement, trip generation, and other changes in travel characteristics can be incorporated into a new generation of models.

TELECITY DEVELOPMENT STRATEGY
FOR SUSTAINABLE, LIVABLE COMMUNITIES
THE BLUE LINE TELEVILLAGE IN COMPTON, CALIFORNIA

WALTER SIEMBAB

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Based On A Presentation At
Rail-Volution
Washington DC
September 8, 1996

Introduction to TeleCity

Central to the concept of livable communities is the idea ofproximity between residence and the essential elements of daily life, such as work places, schools, civic facilities, shopping opportunities and parks. This human scale organization of urban living means that the personal automobile and its related facilities-wide streets and parking lots-are not required and can be replaced by walking, public transit and more human scale technologies, including bicycles and golf carts.

Towns and neighborhoods considered "livable" will have centers that reflect the unique characteristics'and needs of each residential community. Each center will 'have a functional relationship with its immediately adjacent communities.

These ideas of urban life are reminiscent of cities as they were often built in the past—before post-war suburban development fixed the need for an automobile into the land use pattern by creating large scale concentrations of single function buildings, such as housing tracts, shopping centers and office parks.

But while the principles of livability can guide land use patterns in new development, auto orientation remains in the existing built environment. The simple fact is that new development, no matter how perfectly designed, contributes only a minuscule change to the built environment. It is unlikely that significant progress can. be made toward reducing automobile dependence if change is based on new construction alone-through in-fill, redevelopment, and new towns.

Fortunately, new information technologies—characterized by . unprecedented improvements in price-performance ratios-are available for application to urban redesign. Furthermore, the models of livable communities proposed to date do not meaningfully incorporate the powerful capabilities of these new technologies;

It is possible for land use patterns to reflect the capabilities of information technologies comparable to what has occurred around the capabilities of the automobile. And it is possible and affordable to do this as a *retrofit* of the existing built environment. In this way, even an automobile suburb can be made to function as if it was a traditional village. In other words, the auto dependent functional characteristics of the existing built environment can be changed.

The TeleCity Development Strategy is how this can be accomplished.

Vision of TeleCity

TeleCity refers to the city-of-the-future where information technologies are used for mobility, economic growth and other long term public interests, as well as the short term private interests usually satisfied by competitive markets.

TeleCity physically looks a lot like the metropolitan area that is currently home to most people-but it functions much differently. For example:

- Trips outside of the home are much shorter, usually no more than a few miles.
- Economic opportunities are distributed more equally throughout the region, not concentrated in employment and retail centers.
- Most communities include a mixture ofmoonlighters, free lance workers, self-employed, small businesses owners and employees, and corporate employees-many of whom telecommute.
- Some households own only one automobile.
- Public transit is different, more local, smart, less route specific, affordable — and heavily used.
- Groups of neighborhoods form an Urban TeleVillage which has a center that functions as a point of entry to electronic markets and public transactions, and offers rich opportunities for face-to-face interactions for TeleVillage members.
- Centers actually serve and are used by the people that live in proximity to them.
- Urban TeleVillages encourage self-sustaining neighborhoods in that they enable residents to "co-produce" many government services.
- Some parking lots have been converted to affordable housing or community gardens.
- Ground transportation in neighborhoods moves slowly and the vehicles consist of a mix of people-powered-vehicles, electric carts, public transit systems, and traditional automobiles.
- Everyone has access (from on-demand to first-come, first-served) to the full range of information technologies at a location no further than the TeleVillage Center.
- Some homes have state-of-the-art home offices and home entertainment complexes, but most homes have a mix of technologies that are old and new, simple and full featured, poor and powerful.

All of this can be accomplished with very little new physical construction and no dramatic changes in living density. There are no technical or economic barriers so that, with political will, it is achievable in most places within 20 years. It requires only comparatively modest capital investments in infrastructure so that it is an affordable strategy. Finally, the

TeleCity Strategy can ensure the environmental integrity of new development, AND, because it is a retrofit strategy, it can improve existing cities regardless of their current density..

The TeleCity Strategy depends on' a coordinated' public-private effort to bring about mutually reinforcing changes in five key regional systems..

TeleCity Strategy

Public and private sectors must work together to develop:

1) A hierarchical network of advanced communication centers which forms the physical infrastructure for residents to shop, work, take classes, enjoy entertainment, receive government and medical services and so forth, all withinwalking. distance or a maximum of a few miles from home. Each center satisfies a high percentage of the trip needs of the residents and businesses within its service area. Each center includes. commercial, institutional and public non-profit facilities. A. three level hierarchy is proposed—Neighborhood TeleCenter, TeleVillage Center, and Central TeleDistrict. Centers will be located at rail stations where rail systems exist.

2) Distributed organizations which will emerge as traditional, centralized organizations restructure themselves to become more competitive in the global economy. Distributed organizations rely on telecommuting, teleconferencing, teleservices and teleprocessing to conduct business. Each organization, whether public 'or private, will view its telecommunications network as a strategic asset asimportant as its physical facilities.

3) Shorthaul transportation technologies and systems that serve home-to-nearby-center and center-to-center trips. Neighborhood TeleCenters and TeleVillage Centers become transportation hubs. Human-powered vehicles and low performance electric vehicles are used extensively for neighborhood transportation, while smart shuttles, larger electric vehicles and rail systems, serve the TeleVillages and Central TeleDistricts.

4) Universally accessible telecommunications networks that provide sufficient, affordable. bandwidth for the planned applications. Commercial, public/institutional and public/non-profit networks are cooperatively developed. A level playing field for commercial interests is maintained as all commercial carriers pay into local government's, general funds for rights-of-way and spectrum use. Each local government maintains a "telecommunications trust fund" which is dedicated to the development and support of public/institutional and public/non-profit networks and nodes (e.g., TeleVillage Centers).

5) Institutional infrastructure to provide the sustained leadership and. support,, for the regional development effort that leads to TeleCity. At least two institutions are needed--one for management of the public/institutional and public/nonprofit networks and one to work with organizations throughout the region to develop the 'network applications that define the transition from centralized to distributed organizations.

The Blue Line TeleVillage in Compton, California, is the first Urban TeleVillage and the first manifestation of the TeleCity Strategy.

THE BLUE LINE TELEVILLAGE IN COMPTON, CALIFORNIA

Many aspects of this demonstration project could be described, including its policy history, design, development steps, local and regional politics, institutional relationships, staffing, marketing, operating policies, economic development potential and so forth. This brief discussion focuses on its technological infrastructure and functional characteristics at the end of its 3 month beta test.

The Blue Line TeleVillage (BLTV) began a one year demonstration period on March 1, 1996. During its first three months, the facility was open for use about 20 hours per week. The intent of this initial period was to develop administrative systems, test technical systems and develop applications responsive to community needs. On June 3, operating hours increased to 50 per week and full scale operations began.

The discussion begins with a summary of background information, continues with a description of the technological infrastructure and ends with the planned applications.

Description

The Blue Line TeleVillage Center. is a state-of-the-art community center located adjacent to the Metro Blue Line (a 26 mile light rail system that connects the central business districts of Los Angeles and Long Beach) at the Transit Center in the City of Compton. The Los 'Angeles County Metropolitan Transportation Authority (MTA) funded both the planning for the TeleVillage and a 12 month operational period.

The City of Compton is a low income community whose residents tend to depend on public transportation (rail **and** bus) for mobility in a region- dominated by the private automobile. The TeleVillage 'is a new idea for improving mobility and for developing economic opportunities. Within five years, the TeleVillage is intended to ***virtually*** function like a traditional village center. That is, it will provide physical access to electronic markets, services and transactions. Residents will go there to:

- work
- shop
- take a class
- meet friends after school
- become computer literate
- get medical advice
- conduct government transactions
- get all kinds of information
- use computers
- produce a video program

- conduct a video conference
- hold a meeting

All of these activities will be possible because the Blue Line TeleVillage will be connected to participating schools, hospitals+ 'medical clinics; government offices, employers and retailers by a high capacity telecommunications network.

If the idea proves feasible, a TeleVillage might be built at other Metro Rail Stations along the Blue, Green or Red Lines, at civic centers, or in neighborhoods throughout Southern California.

Lead Organizations

Lead roles in the demonstration 'are being played by the Los Angeles County Metropolitan Transportation Authority and Drew Economic Development Corporation.

Los Angeles County Metropolitan Transportation Authority

The MTA is providing the funds for the planning, design and implementation of this demonstration project. It was originally going to provide, some level of network services, but that will not occur during the demonstration period.

Based on its regional mobility mission, the MTA is.most interested in what can be learned from the BLTV demonstration about -the utility of telecommunications services and the performance of the TeleVillage as an activity center that reduces trip length and increases transit ridership.

Drew Economic Development Corporation

Drew EDC, with subcontractors Community Resources, and Siembab Planning Associates, won a competitively bid contract with MTA to plan, design a&implement the Blue Line TeleVillage.

The Drew Team's responsibilities to open the project include'the following:

- support the Advisory Board
- recruit employers to participate in the telework center
- provide technical assistanceto all program sponsors, such as the telework center operator
- recruit resource partners and solicit in-kind and cash donations
- recruit service partners and help them develop their programs

Advisory Board

An Advisory Board represents the needs and interests of the community and has helped determine the specific services and policies of the TeleVillage. The Advisors has 35 members, primarily representing the greater Compton community.

Service Area

Based on the 1990 census, 28,000 people live within 114 mile of the TeleVillage, 33,000 live within ½ mile and 180,000 people live within 2 miles. Over 6,000 people a day get on or off either the rail system or the 6 bus lines that serve the area at the Compton Transit Center. Of these, 43% are rail and 57% are bus passengers.

Description of Initial Elements

The Blue Line TeleVillage will develop six elements during its demonstration year. This design is roughly equivalent to a neighborhood level center in the future. The scale of this demonstration project is small so that it is affordable and so that it can take roots and grow in the community that it serves.

Video Conference Center

This room will seat up to 16 people in either a classroom or a meeting configuration. The equipment is a CLI Radiance system with dual 32" monitors. Conferences will normally utilize three ISDN lines, but 6 are available when higher resolution is required.

Initial applications will include:

1) Distance education classes provided by California State -University at Dominguez Hills and, eventually, other'educational institutions throughout the region, state, nation and world. Classes will range from accounting practices for small business to web surfing, and from English-as-a-second-language to parenting skills.

2) Library services such as story telling for children and lectures for adults from city libraries located elsewhere in the region. Drew Head Start for pre-school children and Drew Day Care programs are located adjacent to the Video Conference Center and can provide an on-site supply of children for these programs.

3) Job-related services such as presentations on finding jobs in the state or federal governments.

4) Political meetings between elected officials from the southeast, south central and south bay sub-regions and their counterparts in central Los Angeles, or officials in Sacramento to Washington DC.

5) Contract training for employers located in the greater Compton area. Classes can range from basic skills to computer aided design.

Kiosks

The main hall of the building will hold a variety of kiosks. These include the Caltrans Smart Traveler kiosk which provides access to basic information about the region's public transit and highway system;-an automatic teller machine from Wells Fargo Bank; the kiosk of the Housing Authority of the City of Los Angeles which allows access by the general public to job and consulting opportunities with the Authority and to information about the mission of the Authority; the AIDS Information kiosk provided by the County Museum of Science and Industry which provides access to a self-guided tour of the facts about AIDS. At least two additional interactive transactional kiosks are being sought.

Computer Center

The Center is equipped with 12 IBM Pentium-90 computers, a local area network with a Compaq Prolinia server rurming under Windows NT, and a Hewlett-Packard laser printer. The LAN is connected to the Internet via 4 ISDN lines. The Internet. provider is Break Away Technologies, located in the Crenshaw district of south central Los Angeles. The initial software on the server includes Windows 95 and the Microsoft Office Suite.

Applications will include:

1) Public access computing-times when members of the public can gain access to a computer to pursue personal or business goals.

2) Courses for adults and children ranging from basic computer literacy to training in the specific software packages on the server. These classes will serve community organizations including the Watts-Willowbrook Boys and Girls Club, rehabilitation programs, non-profit corporations, and churches.

3) Internet access, especially employment and job training opportunities for adults, and exploration experiences for children. The Blue Line TeleVillage will register its own domain and TeleVillage members will receive their own an e-mail address and have the opportunity to create their own home page.

Telework Center

The Telework Center is being hosted by the Business Assistance Center of the City of Compton. It consists of two work stations each, equipped with computer, laser printer, telephone, and modem. There is, in addition, an Intel ProShare computer for desk top video conferencing which is supported by 1 ISDN line.

Applications include:

1) Professional work space for telecommuters—residents of the greater Compton area who are employed in businesses located elsewhere. The County of Los Angeles has one of the most advanced telecommuting programs in the nation and several County employees who normally report downtown or to other facilities will telecommute 2 to 4 days per month from the Blue Line TeleVillage Telework Center.

2) Professional work space for teleworkers -residents of the greater Compton area who are self-employed and/or a home-based -business' who need occasional access to a professional work station. The objective is to encourage start-up businesses and the growth of very small businesses.

3) Training sessions to interested local entrepreneurs and businesses on the use of desk-top video conferencing, including the screen sharing capabilities that facilitate collaborative work.

4) A mentoring program between students and faculty with entrepreneurial expertise at a graduate business school in the region and entrepreneurs from the greater Compton area-with interaction conducted primarily over the telephone and the desk-top video conferencing unit.

Public Lectures and Presentations

A range of live, in-person educational programs will be presented in the Community Room under the auspices of the Blue Line TeleVillage. For example, Wells Fargo Bank has agreed to provide a program on consumerand small business banking issues.

Television Production Capability

The Blue Line TeleVillage will be equipped with portable video recording and editing equipment and capable of originating live signals for downstream distribution over the local cable television system. This will allow the TeleVillage to record and distribute the live, in person educational programs as well as to develop special presentations for video such as a home-shopping program featuring businesses from the greater Compton area.

Circuit Rider Work Station

One work station in the administrative area of the Blue Line TeleVillage will be used by "circuit riders"—employees of a variety of government agencies who appear at the Blue Line TeleVillage on a regular schedule to provide jnformation or directly deliver services.. There are no current circuit rider commitments, but a twice-a-month visit by a benefits counselor from the Social Security Administration is an example of what will be developed.

Additional information on the TeleCity Development Strategy and the Blue Line TeleVillage are available directly from Mr. Siembab.

GOODBYE UGLYVILLE, HELLO PARADISE: TELEWORKING AND URBAN DEVELOPMENT PATTERNS

MELVIN R. LEVIN

For some people the defining moment is a car breaking down in a blizzard on the way to work, the third burglary or perhaps the first mugging. For others, it is the long, long crawl to the office when the soothing tape deck can't compensate for an over-stressed bladder. Cold, crime, congestion. All have a jarring impact on the exasperated, the frustrated, the frightened and the just plain angry.'

They wonder: Can we stretch our vacation at a balmy resort by weeks or months when the wind-chill factor at home hits ten below and lingers? Can we avoid the morning rush hour? Could we live in a green place far out in the country, safe from street, thugs and the need for three dead bolts and a stranger-averse dog?,

A few years ago, the answer would have been "not likely.': Work was cemented in an office, 9 to 5; the dailycommute only a half hour off peak but close to an hour drive in rush hour traffic. Now new technology and new approaches may bring liberation. The new technology is the computer.

Today employers throughout the nation are encouraging-and sometimes forcing-people to work at home (or at-least out of the office) because through the computer they can save on employee office and parking space and on time formerly spent commuting that can be put to better use. At the same time employers can retain valued home-bound employees while closely supervising computer-based output.

How Many, How Much on the Way?

There are two ways to look at the impact of telecommunications technology. The narrow view is to focus on telecommuters. The broader perspective includes the self-employed teleworkers who use this technology as an adjunct to the mail and telephone.'

The US Department of Transportation estimates that there were two plus million telecommuters in 1992 who were telecommuting on an average of 1-2 days per week. This represented only 1.6 per cent of the labor force, far below other estimates. By 1994, the number of corporate employees who telecommute rose from 2.4 million in 1990 to 6.6 million.

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[1] Office of Technology Assessment, The Technology Reshaping of Metropolitan America, (Washington, US Government Printing Office, 1995), pp. 165- 166.

By 2002 Department of Transportation (DOT) predicts that the total number of telecommuters will reach 7.5 to 15.0 million people telecommuting an average of 3-4 days per week. This amounts to 5 to 10 percent of the labor force in 2002.[2] Another estimate is that the figure will climb to 11 million by 2000. If self-employed workers are included, these numbers rise by 25 to 30 per cent or about one worker in every nine or ten. [3] A more optimistic estimate puts the upper level at 25 million by 2002 or possibly one in six workers.[4]

Another estimate, based on a combination of government and corporate statistics is that 39 million people (roughly a third of the work force) already do some work out of their homes. Of this total almost 24 million operate home businesses, half full time, half part time. An estimated 6.6 million are home telecommuter employees who work at the office from half-a-day to two days a week. The remainder 8.6 million, work at home after office hours. Many are only a short distance away from some telecommuting.[5]

How fast is the number of teleworkers growing? The Southern California telecommuting partnership puts the nine month gain in Southern California in 1996 at an astounding 11 per cent. There is a special factor in this area: "Nine out of ten people who started telecommuting after the Northridge earthquake still do it."[6]

<u>How Much? How Many? Other Estimates</u>

As the data suggest, there is no consensus on the number of people who work full time or part time at home let alone those who avoid the downtown commute by working in small suburban office centers. In mid-1996 a *New* York *Times* story reported that

> As many as 40 million people work at least part time at home with about 8,000 home- based businesses starting daily... some 1.5 million claimed deduction...on their tax returns for

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[2] Ibid, p. 170.

[3] Ibid

[4] Jack Nilles, JALA International, Inc. "Telecommuting Forecasts," Los Angeles, CA. 199 1, cited in Office of Technology Assessment, p. 170.

[5] Richard Nelson Bolles, <u>The 1996 What Color is Your Parachute?</u> (Ten Speed PressBerkeley, 1996), p.115

[6] Karen Kaplan, "For Workers, Telecommuting Hits Home," <u>Los Aneeles Times. July 29. 1996. p. D7</u>

1993.[7]

The ten places with the highest percentages of residents who work at home include cities as well as upscale, high tech suburban areas ranging from San Diego and Manhattan to Beverly Hills, Bethesda, Berkeley, Austin, Greenwich, Ct.; Santa Monica and Calabasas/101 Freeway, CA. The percentages range from 5.2% to 9.4% of the work force. But this does not mean that these 'people are all out of the commuting loop. Only about two-fifths are either full time self employed or do all of their work from home. The majority are part-time self-employed or employees who do work at home after hours.* Hence the small number of claimants who can meet stringent IRS criteria for office deductions.

The ranks of telecommuters-or more accurately teleworkers (if we include the self-employed) have been burgeoning thanks to a basic change in the US employment pattern. This is the shift to temporary and part time work that reached record levels in 1994. More than one-fifth of the nation's work force-24.4 million Americans-had only part time or temporary work. Construction, mining and manufacturing where wages averaged from $530 to $630 a week, were shrinking, while service and retail businesses where the pay averaged from $200 to $370 a week were growing.' This may be bad news for many once secure workers.

Time magazine adds its version of a total number 3 million US employees (as of 1995) telecommuting full or part time; the number growing at a phenomenal 20 per cent per year.[10] Clearly, a 10 or 20 percent annual gain in telecommuters is unlikely-unless we take into account the part timers, who make up a major share of the total. This estimate is based on a minimalist definition, i.e.,

> . ..someone who works from home as little as one day a month, during usual business hours...that telecommuters work at home an average of 39.6 hours a month--& only about 12 weeks a year—means that most work' is still done at the company office.
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> Chiat Day, an advertising agency, has replaced offices and filing cabinets with couches. Given their druthers, almost half

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[7] Jon Nordheimer, "You Work at Home Does the Town Board Care?, The New York Times. July 14, 1996, P.l. Sec.3.

[8] Ibid, p.10, sec.3

[9] Hedrick Smith, Rethinking America (Random House, New York),1995 p.210

[10] Time ,"Special Issue, Welcome to Cyberspace," Spring 1995, p.37.

> the staff telecommutes from home or the road via pager, cellular phone, computer and modem. There is a 'concierge desk' where employees can book an office, pick up a laptop computer and portable telephone. One vestige of old times is conference rooms. Paper "has all but vanished" in favor of messages on personal computer screens.. The homey collection of photos, plants and souvenirs once found on and around private desks and offices are gone; personal effects are stowed in employee lockers."

As Jeremy Rifkin writing in The Nation states Automated technologies have been reducing the need for human labor in every manufacturing category. Now, however, the service sector is also beginning to automate In the banking, insurance and wholesale and retail sectors, companies are eliminating layer after layer of management and infrastructure, replacing the traditional corporate pyramid and mass white-collar work forces with small, highly skilled professional work teams, using state-of-the-art software and telecommunications technologies. Even those companies that continue to use large numbers of white-collar workers have changed the conditions of employment, transferring workers from permanent jobs to "just in time" employment, including leased temporary and contingent work, in an effort to reduce wage and benefit packages, cut labor costs and increase profit margins.[12]

All told, at least 80 per cent of all employed persons will probably not be awarded the flexibility in routine and location resulting from advances in telecommunication.

For those in the remaining 20 per cent there will be more flexibility. College professors are one historically autonomous group, predating the computer, a profession famous for flexible hours and independence. Writers and artists supported by their profession would also fall in this category. What is new is the increasing numbers of back office staff of computer programmers, researchers, management analysts, financial staffers and marketing personnel who are now working away from central offices or who can and will be doing so in the course of the next decade.

Even at that some of this group are optional. Travel agents, word processors, legal assistants, some engineers and scientists, business entrepreneurs, bill collectors and many others can work out of their home or away from the central office at least part of their time or enough to get on an extra day or two at home or to avoid peak hour travel.

In short, it is not either/or, professors vs sanitation workers, traveling salesmen vs the assembly line.

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[11] Ibid, pp.38-39

[12] Jeremy Rifkin, "Civil Society in the Information Age," The Nation, Feb. 26, 1996, p. I l.

The predicted world of rich knowledgeable workers and poor service workers will have many exceptions. There will still be affluent plumbers, and well-paid specialists in foreign car repair and restoration, of old masters. One question is whether underpaid, disaffected, low-skill workers will become a breeding ground for civil disorder? We know that the marginals, the dysfunctional underclass, is the source of serious social ills.. The question is whether the equivalent of the displaced bank teller, the army of minimum wage retail order takers and product baggers, the ex-draftsmen, telephone operators, stenographers, laborers and others scrambling for a bare living will become a legion of resentful *lumpen*, open to conspiracy theories and xenophobia.

Cornorate Teleworking from Privilege to Mandatory Requirement

One stimulus to telework is the Clean Air Act which started in November 1994 mandating in 13 highly populated regions that firms with 100 plus employees at one site must submit and implement plans for reducing peak hour commuter traffic. However, the real thrust comes from economic, not environmental or personal gratification incentives. The key is reduced costs for office and parking space as more employees are shifted out of the head office plus there is the promise of increased, easily monitored productivity by cutting back on wasted commuting time and office distractions.

It is clear that the numbers of volunteers is being overtaken by conscripts; employees ordered to work at home or at an off-site center. The trend toward mandatory teleworking picked up steam in the mid- 1990s.

Business Week estimates that 83 per cent of US companies are now embracing alternative office strategies. The American office is evolving rapidly in two directions. The first is reorganizing workspace for those employees "who must still work in offices" and the second is "shoving everyone else out the door."[13]

To critics who fear isolation of employees and loss of control by management, there are three responses:

First, measurements of output and productivity are often easier to assess when the work goes over the computer. Pretend-work is harder to generate in the homebased office than in headquarters with its froth of meetings and memos. One of the reasons that corporations are so readily taking to the practice is the belated discovery that its usually easier to keep tabs on telecommuters than on office staff.

Second, the loss of personal contact is exaggerated. Serendipitous encounters around the water cooler and the coffee machine are still operative. Why? Most telecommuters do not stay away all the time. Frequent office lunches, morning or afternoon meetings still take place. Remember, telecommuters are classified as such if they work outside the head office

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[13] "The New Workplace," Business Week, April 29, 1996, p. 109.

one day or more a week. Most are at the central office at least one or two days a week.

Third, as telecommunications bandwidths and process costs decline, we will see more videoconferencing, virtual meeting places and, very soon, two way visuals. A decade hence we may have three dimensional holograms which offer a reasonable facsimile of face-to-face encounters.

It would seem that telecommuting would be the medium of choice for employees at the big firms like IBM, AT &T and other giants with their sophisticated management style in general and cost containment interests in particular. In sheer numbers, however, the ranks of at home workers who are telecommuting employees are far overshadowed by entrepreneurs. What has happened is small businesses that once relied on mail and telephone have tapped into the potential of telecommunications technology that provides speed and flexibility.

Telecommunications technology gives added impetus to a decades-long trend in the growth of the self-employed.

The May 199 1 Current Population Survey reported approximately 20 million non farm employees working at home as part of their primary job, i.e., about one worker in six.

> Most home-based workers (24.3 percent) are in marketing and sales, 14.9 percent in contracting, and 13.2 percent are in mechanical and transportation, collectively accounting for more than half of all the respondents in the study. Some 12 percent of the occupations are in the services, which include home child care; elder care; processing vegetables for McDonald's, crafts and a variety of endeavors related to the arts, such as composing, film producing, graphic designing, and creating greeting cards; and professional work in education, finance, government, health, law, religion and science. Less than one percent of the job titles are computer related. On average, home workers are 35 or older. More are married rather than single, business owners rather than wage earners, and most work full time. On a mean scale, they have received 13.9 years of schooling, more than is typical of workers in the traditional workplace.[14]

About half the home workers were full timers, a quarter were in marketing and sales, a sixth in contracting and an eighth were truck drivers or in other transportation. Only six percent were employed in clerical and administrative support and about one in eight was a craftsman or artisan, most of them presumably part timers. Interestingly, the average home-

[14] Ibid, p. 16.

based business owner earns about a third more than the average wage earner and there are other advantages.

> At-home work can increase profits by decreasing operating expenses, and eliminates hours spent on the road and away from home. Federal tax regulations allow self-employed home-based workers to shelter profits under reinvestment, retirement, and other plans. New technology, a growing pool of temporary workers, and new home-based support services that provide everything from document archiving to conference space are making home-based work more 'professional', more affordable, and more appealing."

One of the unexpected findings of the mid-l 990s surveys is the high percentage of city workers who work out of their homes; teleworking is not just for suburbanites.

% WHO LIVE & WORK AT HOME

Downtown San Diego, CA	9.4
Midtown Manhattan, NY	7.1
Downtown Manhattan, NY	7.0
Century City/Beverly Hills, CA	6.4
Bethesda/Chevy Chase, MD	6.1
Austin Downtown, TX	6.0
Berkeley, CA	5.5
Greenwich, CT	5.5
Calabasas/10 1 Freeway, CA	5.2
Santa Monica, CA	5.2

Home Office Computing, Nov. 1996, p.24.

Surveys reveal another interesting finding the data appear to demonstrate a strong gender difference; Two thirds of home businesses are owned by women. By category the largest single home business category is business support services followed by desk top publishing, consulting and retail sales from home. All told, these four sectors account for almost two thirds of the total.[16]

The seers who follow the great American tradition of looking optimistically into the future after each new invention have greeted telecommunication as the pathway to all sorts

[15] Ibid, p. 18.

[16] Home Business News Report. PT Corp,1996.

of joy to come. Following the yellow brick road to Oz will find the elderly, the frail and the disabled granted the gift of mobility and employability. Persons trapped at home as care givers for the elderly or young children will be able to hold part time or full time jobs. Everyone who can pay the small entrance fee for the requisite equipment can enter a fascinating world of entertainment, information and constant contact with friends, relatives, colleagues and fellow members of and interest groups.

In the late 1990s, the pattern is pretty much a matter of current computer-phone-fax technology. The publication, ***Home Business News Report,*** sees elaborate video conferencing rooms giving way to desktop conferencing but does not speculate on the significance of universal visual communication.[17]

In short, up to the early 1990s telecommuting was seen as a kind of rare privilege granted to self-disciplined employees who could make a convincing case for leaving an empty desk at the office. Increasingly, it is the employer who insists and the employee who must accede. For example, aggressive telecommuting programs at Pacific Bell resulted in one quarter of the 19,000 workers telecommuting at least one day a week, and similar efforts were under way at Compaq, Perkin-Elmer and Hewlett Packard. These are all leading-edge firms based in California. When the Los Angeles earthquake added to chronic peak hour traffic congestion, it spurred the trend toward structured programs aimed at cutting corporate operating costs. Companies have decided to reduce office costs, parking spaces, motor pools and lost travel time by ordering employees—usually beginning with the sales department-to work away from the central office. It is noteworthy that Denver's travel reduction program, TRP 2000,'aimed at "squeezing every nickel" teaches management teams to save money with innovative work strategies.

The city and county of Denver's three day certificate program advertises that "its graduates include executives from life insurance, airlines, utilities and other firms." Managers should be "work product-oriented." Benefits include retraining valued trained employees, reductions in office space, "happier, lower stressed employees in terms of medical costs, sick days, absenteeism and burnout..." The brochure for the program asserts,

"Telecommuting is a win-win-win concept. . . ." It further states, "telecommuters are happier and more productive as are their families, their employers benefit from economic and efficiency gains and their community infrastructure is helped by their presence."[18]

Xerox has its virtual sales office program for sales reps in its southwest sales and marketing territories. Xerox sales reps have been given the tools that largely eliminate the need to come into the office. Instead district offices will act as business hubs used by roving

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[17] Ibid, p. 117.

[18] Ibid

employees.[19]

One basic incentive is available to the draftees. While. the volunteer telecommuters willingly assumed the costs of equipment for home offices, the employers pay the expenses for the new breed of conscripts.. This can include office furniture, computer, printer, software and fax and one or two extra phone lines. Why two? One is for checking e-mail,. faxes and connecting to home office computers and the other is for business voice calls; Hewlett Packard supplies telecommuters with duplicates of home office UNIX workstations. The cost approximately $4,000 per year per employee. The payoff, more productivity.[20]

Perkin-Elmer offered substantial incentives -for its sales and. service engineers when it consolidated its outlying sales offices into seven. Each employee received a laptop computer with modem, two telephone lines and a $1,000 furniture allowance.

Hewlett-Packard offers the telecommuter alternatives to an increasing number of non "field" staff like design engineers who need blocks of uninterrupted time transcending standard office hours.

Given huge cost savings from reduction in office space needs, large firms have begun to leap into telecommunication technology, a trend that is beginning to have an impact on federal employees (state and local are a decade behind).

The world of work is changing fast, choices about where to live and work are increasing by quantum leaps, particularly as technology-oriented boomers move up to senior management status.

Mokhtarian suggests that the 8.2 million telecommuting employees in 1995 could be substantially increased were it not for manager unwillingness. The estimate of 16 percent of the US labor force that can telecommute shrinks to only 6.1 percent partly because of this employer resistance. In real terms, given the 1-2 a week typical telecommuting pattern, this translates into a minor 1.5 per cent reduction in highway travel. It seems to be likely that manager resistance is replaced by manager insistence.. To accelerate the move out of expensive- headquarters office space, the trend toward teleworking will accelerate 'with significant impact on travel and land use patterns.[21]

By the mid-1990 's services can be provided by countries thousands of miles apart as

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[19] Deborah Lewis, "Telecommuting Round Two-Voluntary No More," Forbes ASAP, Oct.9, 1995, pp. 133- 134.

[20] Ibid, p. 138.

[21] Patricia L. Mokhtarian, "A Synthetic Approach to Estimating the Impacts of Telecommuting on Travel," paper prepared for the TMIP Conference, Williamsburg, VA, Oct.27-30- 1990.

the transmission of information will permit and indeed foster enormous changes. Proximity is no longer a given. Possibly, the pressure for opportunity-driven migration from third world nations will diminish as professionals can remain in place while working for a far off first world corporation. On the other side of the world, skilled professionals in advanced nations will find themselves under siege by lower-paid third world competitors: And in rural and remote areas in the first world telecommunications may open up opportunities for local professionals and migrating workers from big cities.[22] The prescription cannot be made generic. The key issue will be the relative attractiveness of local amenities. A staggering number of communities offer very little for people with wide residential options.

The Economist foresees a world where the "death of distance" will mean that

> . ..any activity that relies on a screen or a telephone can be carried out anywhere in the world. Services as diverse as designing an engine, monitoring a security camera, selling insurance or running a secretarial paging service will become as easily exportable as car parts or refrigerators.[23]

Among the "glimpses" of the world of the future, we see India attracting back-office work from Swiss Air and British airways as well computerized monitoring for monitoring air conditioning, lighting, and lifts elevators in Singapore, Malaysia, Sri Lanka and Taiwan.[24]

None the less, most people have no choice. They have the kind of job that makes it impossible or unlikely to avoid the traditional 9 to 5 routine. It's not just assembly workers who have to be there; nurses, attendants, cashiers, most retail sales clerks, janitors, waiters and cooks, gardeners, policemen and firemen, doctors, carpenters and teachers, mechanics, farmers, miners, fishermen, and receptionists have to be there in person at regular hours.

Telecommunications and the New Urbanism

The telecommunications revolution links economic activities that don't have to be in physical proximity. It offers more freedom to choose where people work, live and go for 'recreation. The big question facing US urban areas in the next generation is: where will people choose?

We must also take into account that many other factors are at work. For example, retail and wholesale trade may be considerably changed via home shopping but it is likely that the advent of the big boxes-Walmart etc.-has had more effects on retail trade than

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[22] "The Revolution Begins, At Last," The Economist. Vol. 336, No. 7934, Sept.30, 1995, pp.15, 16.

[23] Ibid, p.227.

[24] Ibid, pp.27-28.

sales via computer or television.

There can be no quarrel with Graham and Marvin's depiction of urban areas as much more than aggregations of structures bound by traditional linkages. In their view

> . ..contemporary cities are not just dense physical agglomerations of buildings, the crossroads of transportation networks, or the main centers of economic, social and cultural life. The roles of cities as electronic hubs for telecommunications and telematics networks also needs to be considered. Urban areas are the dominant centers of demand for telecommunications and the nerve centers of the electronic grids that radiate from them. In fact, there tends to be a strong and synergistic connection between cities and these new infrastructure networks. Cities-the great physical artifacts built up by. industrial civilization-are now the powerhouses of communications whose traffic floods across global telecommunications networks-the largest technological systems ever devised by humans?

What is important are the next questions. Which cities fit best into this new world? Which areas outside central cores will come aboard and which will lag? In short, in an era of choices, who will be chosen and who will be rejected?

We can agree with Graham and Marvin that in this emerging urban world there is an inherent logic of polarization, which seems to be locked into current processes of economic and social development in cities. This polarization is both reflected in, and supported and reinforced by, the development of electronic spaces. Fewer city economies seem set to do well; patterns of economic health become more starkly uneven at all spatial scales; and processes of change seem to reinforce the privilege and power of social elites while marginalizing, excluding and controlling larger and larger proportions of the population of cities. [26]

John Keegan sees the decline of older US cities as inevitable, victims of emerging technologies that shifted the focus of development outward. In his view

> The old cities have lost their hearts because they were built by people who thought at a foot's pace, journeyed. by horse. The vastness of America, for all the heroism of early journeys made

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[25] Stephen Graham and Simon Marvin, Telecommunications and the City, (Routledge New York, 1996), p.3.

[26] op. cit. Graham and Marvin, pp.378-379

> by foot or horse into its unexplored interior, demanded other means of motion, the locomotive, the motor car, the airplane, means of devouring space, not of submitting to it. It is the space that surrounds American cities, the interminable distances between them, that have done for small streets and town squares, felled the shade trees, left the porticoed churches standing amid desolation, driven freight yards and interchanges and airport expressways into the order that 'once was. It could not have been otherwise. Once Americans decided to command their continent from coast to coast, all three thousand miles of it, to have no internal frontiers, to spend a common currency, to obey, often not to obey, a uniform code of law, to recognize a single government, to be one people, the life of the small city, the shape of the pedestrian neighborhood, was doomed. Traveling America confronted settled America and traveling America triumphed.[27]

Keegan overstates his case, particularly when he expresses admiration for a number of old cities that have retained charm and vitality, cities like Charleston and small towns like Annapolis and Stonington, Connecticut. But the thrust of his argument is difficult to counter, particularly in the context of heightened sensitivities to crime and disorder.

Graham and Marvin cite the response of a prominent British urbanist, Richard Rodgers, to the crucial issue of the survival of central cities in an era of social and geographic polarization.

> What, he asked, would be the fate for Britain's cities if a new set of urban ideals, and the mechanisms to achieve them, were not built up to address the growing sense of urban crisis in Britain? Rodgers's response was stark and simple "Blade Runner": "The poor will be ghettoized in their estates, walled in by police and by the barriers of unemployment. The rich will be in their ghettos too, electronically and fortified. Everyone will be separated in his or her own security castle. There will be no society." . ..much of what we have found in this unprecedentedly broad review does seem to support Richard Rodgers's rather pessimistic outlook. As part of the ongoing economic, social and cultural change surrounding the shift to post-modem urbanism, telematics do seem to be helping to support the emergence of new, more highly polarized social and cultural landscapes in cities. The truly public dimensions of cities where citizens interact and encounter each other in

[27] John Keegan, Fields of Battle. (Knopf New York) 1996, p. 16.

> physical space seems threatened. Urban trends seem to be supporting instead a shift towards tightly regulated private, and semi-private spaces--both physical and electronic--oriented towards the exclusion of groups and individuals deemed not to belong. [28]

As one cynic puts it, the information highway is the only highway that doesn't go through the ghetto. (This refers to the fact that in-town roads tend to avoid upper income neighborhoods and seem to be magnetically drawn to slum areas.)

We can reasonably suggest that teleworking will accelerate--give added impetus--to trends that were in full operation before the first computer was unpacked from its crate. What can we realistically expect in the next ten to twenty years?

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[28] op.cit. Graham and Marvin, pp.234-235.

SUBSTITUTION AND COMPLEMENTARY EFFECTS OF INFORMATION ON REGIONAL TRAVEL AND LOCATION BEHAVIOR

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ABSTRACT

Current thought on the impact of information technology on society generally argues that it will, among other things, increasingly become a substitute for trip taking. There is also a school that argues that it is also emerging as a compliment to transportation.. This paper examines these arguments through a literature review with model development and numerical experimentation. The conclusion is that substitution effects: will be sufficient to induce concentration of new growth in U.S. metropolitan regions far beyond the current "edge city" periphery.

A paper prepared for presentation at the workshop: New ***International Perspectives on Telework***, Brunel University, West London, England, July 29-August 2, 1996.

1.0 Introduction.

The purpose of this paper **is** to explore the substitution and complementary effects of information on travel behavior and metropolitan **spatial form.**

One of the last reports produced by the U.S. Office of Technological Assessment before it was terminated' in September 1995 **was The Technological Reshaping of Metropolitan America.**[1] This report provides a thorough review and assessment of the technologies that will impact urban and regional form. In particular they focus on the location of employment,

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[1] Office of Technological Assessment. **The Technological Reshaping of Metropolitan America OTA-ETI-643** (Washington, D.C.: U.S. Government Printing Office, September 1995).

location of information-based service industries, location of freight transportation, distribution of manufacturing jobs, and the pattern of transportation and telecommunications infrastructure in metropolitan areas. The general conclusion is that technology is continuing to reduce the friction of distance for the trip to work and for the need for central locations in metropolitan regions. The implication is that the technological forces propelling metropolitan sprawl will intensify and thereby, if left undirected, contribute to the further decline of central cities which is the chief focus of the report's policy recommendations. The report, at best, marginally addresses the policy and management implications for the "cities on the edge" and for the new exurban concentrations that can be expected to develop. The OTA analysis needs to be extended to assess the implications for these outer city concentrations and metropolitan regions as a whole which is the focus of our analysis and modeling.

2.0 Analysis.

Metropolitan sprawl has long characterized the evolution of the American metropolis. In this part of the paper we argue that technology will contribute to increased sprawl, ***ceteris paribus.*** The analysis first defines the relevant technologies and then describes how they may contribute to the reshaping of U.S. urban structure into a network of relatively equal urban nodes but of greatly expanded urban regions. Related policy and management-issues are examined.

2.1 What are the technologies?

To be sure, technology is not the only factor contributing to metropolitan deconcentration and sprawl. Other factors such as lower land costs on the periphery, extensive highway. systems lowering transportation costs to outer city locations, residential preferences of Americans for the "marriage of town and country" living styles and the vision of a Jeffersonian rural lifestyle, deteriorating conditions in central cities and finally a set of government policies that provides subsidies ranging from tax policies to depreciation allowances to implicit subsidies in the form of building regulations and policies that discourage efforts to reuse older urban and suburban land have traditionally contributed to metropolitan decentralization.* This is to say nothing of the social issues of race and poverty related to segregated spatial patterns. Yet the rapid development and ever quickening deployment of new core technology in the form of computer and information technologies (IT) are making a continuously changing and ever more spatially dispersed metropolitan economy not only possible but a reality. By buttressing communication systems with computer technology a wide variety of electronic communication networks have been developed including local area networks (e.g., to link workers together in an office), wide area networks (e.g., to link the workforce of a large organization across multiple locations and/or multiple organizations) and the Internet which potentially could one day link all people and all organizations together in a global communication network.

Networks make it possible to substitute communication for trips and face to face

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[2] ***Ibid,*** p. 195.

meetings through telework, telecommuting, and telepurchasing, telemarketing and telemedicine technology systems. Electronic networks and communication systems also make it possible to adopt 'practices like just-in-time inventory, continuous adjustment routing and advanced logistical systems. Information technology applied to vehicles and transportation infrastructure (Intelligent Transportation, Systems-ITS)- make it possible to increase the productivity of traditional transportation infrastructure by,' for example, increasing the capacity of roads and thus reducing congestion and increasing mobility. However it would be foolish to think of communication and transportation as pure substitutes; rather they are complements making each other increasingly efficient in an ever quickening interactive society.. Taken together this new emerging set of technology systems is and willcontinue restructuring metropolitan America. It is increasing the ability of individuals and firms to locate far beyond the metro area as we know it even today.

2.2 Reshaping metropolitan America.

The clarity of the core dominated theory of the city was fading as early as the mid-20th century when complementary centers began to emerge at suburban transportation nodes. By late century, these centers as well as new ones further to the periphery had become -Joel Garreau's Edge Cities,[3] large outer city concentrations of business and retail activity that rivaled or surpassed their historic geographic core cities in scale, job generation and range of functions.[4] These new competitive "cities on the edge" differed in ways other than just location, e.g., they had "shadow governments" unlike the elected official headed government institutions of traditional cities. In short, metropolitan space is today defined by multiple commercial centers with one or more having greater attraction than the geographic core. These metropolitan regions,, unlike the more vertically and. linearly structured' core dominated urban regions of the past, may be described-as a network of centers, with the core city serving as an important but not dominant node among a system of nodes.[5] While the OTA report recognizes this emerging network; it fails to examine the myriad of issues that are implied, choosing instead to focus the policy emphasis on -addressing problems of metropolitan 'core cities. To be sure this is an important issue. However, it is not the only one. Here the focus is on metropolitan structure as a whole and on the array of nodes in the region including inner and outer 'edge cities, new edge

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[3] **See** Garreau, Joel. **Edge Cities: Life on the New Urban Frontier,** Doubleday, 199 1.

[4] Stough, Roger R., Kingsley E. Haynes, Harrison S. Campbell, Jr., "Small Business Entrepreneurship in the High Technology Services Sector: An Assessment for the Edge Cities of the U.S. National Capital Region," ***Small Business Economics,*** forthcoming 1996

[5] Brian Berry in his classic paper on "Cities as Systems Within Systems **of** Cities" **Papers in Regional Science** (1964) first presented this concept in an hierarchical framework but Kingsley Haynes, to my knowledge, was the first to use the network metaphor to describe a system of equally important but specialized nodes in a flatter hierarchy for a framework of the new American Metropolis.

cities beyond the periphery of today's metropolis and satellite cities far beyond the existing development fringe.

2.3 Policy issues of the networked metropolitan region.

First, policy at the broad level of scale must be considered in terms of the network; not just in terms of one (e.g., the core) or several of the network's nodes. Second, nodes will play different yet potentially regionally complementary roles and the relative importance of specific nodes may vary over time, e.g., the geographic core was dominant at an earlier time; satellite cities may be the dominant growth centers of the next decade as edge cities were over the past two decades. Third, the technology systems that are unfolding are forces that will continue to propel metropolitan sprawl and as these systems continue to evolve and become more widely adopted they will intensify the sprawl effect. Other things such as current land use and zoning practices at the local jurisdiction level remaining as they are today, sprawl will be the continuing paradigm of metropolitan development.

Assuming for the moment that land use and zoning practice remain unchanged and that sprawl continues, one should ask: What form it will take? Unlike in the past the new technology systems make possible a potential leapfrogging of development centers over the urban fringe to the intermediate and far periphery. Thus, development may follow a spatial leapfrogging pattern with significant growth occurring in existing (satellite) centers as much as 50-75 miles out from the urban fringe. These distant exurban concentrations, while often relatively. small (10,000 to 20,000 inhabitants)\ frequently have significant land and physical infrastructures including good transportation connectivity with other closer in regional centers. Because. of this infrastructure and because of the locational freeing effect the new technologies are having it is likely that these exurban centers will become the primary growth nodes of metropolitan areas over the next decade or two. To the extent there is demand for additional clusters of commercial activity (and there will be in faster growing regions) one can also expect the development of new edge cities in the zone between the current fringe of development and the satellite centers; If one concludes that the new technology makes this leapfrogging sprawl scenario probable, "what are some of the implications for all of the nodes in the expanding metropolitan network?"

First, existing edge cities will, along with the core, join the older nodes in the metropolitan system and thus will be faced with considerable competition from the satellite and new edge cities that have job and business growth and expansion, and probably a high quality of life for those seeking a better balance between "town and country" preferences. Existing edge cities like the core will need to become far more innovative and competitive to hold the jobs and firms that form their economic base because the new nodes will have a relative advantage much as today's edge cities have over the core. Existing nodes will increasingly need to create organized economic development and program initiatives. However, edge cities, at best, have limited institutional infrastructure to carry on these types of activities in a sustained manner given the "shadow" status of their governance. To be sure, edge cities have been able to successfully undertake and deliver uni-functional services such as security and police and beautification. However, there are few, if any, edge cities that have economic development programs that go much beyond real estate development initiatives although some have created non-government organizations to address issues effecting their sustainability such as transportation connectivity and access, e.g., Tytran of Tysons Corner outside of Washington, D.C. Developing and sustaining economic development initiatives while today's edge cities are relative competitive will be a major requirement for survival over the next decade. Further, there is not apt to be much in the way of federal or even state aid to assist in this survival effort although local economic development programs may be 'worthwhile allies.

The vision of a greatly expanded metropolitan network of satellite and new edge cities has significant implications for transportation infrastructure investments. Most of the metropolitan networks have been developed on the basis of a core dominated metropolitan vision. Thus, metropolitan transportation systems are heavily oriented toward a hub (core) and spoke model. Changes in the last half of the 20th century (especially over the last 20 years) have changed the pattern as today the primary demand for metropolitan transportation is for supporting trips across the system (to link edge. cities to one another) rather than to and from the core. The 1990 census showed over and over that commuting patterns were changing from core dominated to network oriented. Connecting this line of argument up with the vision of the networked metropolitan region of the future suggests that transportation infrastructure will need to, increasingly connect a network of nodes that is intensifying within the existing metropolitan region while at the same time linking in new edge cities and satellite nodes at greatly expanded distances.. Demand for transportation of this nature cannot be satisfied with increased heavy rail and transit which is the solution that many see for the geographic core of the metropolitan area. Nor can it be satisfied with Transportation Demand Measures (TDM). Significant new investment in road and' light rail infrastructure will be required, which is the only remotely affordable way to address the growing demand for transportation among the expanded metropolitan network of the future.

Specialized nodes of shopping, arts, business services, manufacturing, and R&D are likely to develop in their own right as are centers with unique historical, architectural or urban artifact elements. Obviously some of the latter will be and are being obliterated but some will survive and become gems of desirability and preservation in this system of urban nodes that will make up the new metropolitan organization.

2.4: Managing sprawl and the expanding metropolis.

The dominant proposal for managing sprawl in the U.S. is to adopt measures that will force greater intensity of development within existing metropolitan clusters and intensify infilling. While the OTA policy proposals seem for the most part to subscribe to this perspective the results of the analysis, as summarized above, show that technology-is and will continue driving decentralization~tendencies. Further, given the diversity of forces propelling sprawl, the "political will" to counter sprawl does not seem to exist although there are some experiments in early stages of development, e.g., the states of Oregon and Washington. There the state has adopted growth control legislation that permits a metropolitan area to first establish boundaries within which growth will be confined and targeted. For example, Portland, Oregon, has identified twenty some centers that are to receive new growth in the-region. The problem with this is that technology is likely to make a number of locations beyond (perhaps even far beyond) attractive for commuters and businesses tied to the Portland regional economy. In short, it is difficult to see

how growth can be confined to a “socially” or “politically” defined area when the cost and benefit attributes of places outside this area have relative advantages for at least some people and some businesses.

So what is to prevent the development of broad, decentralized development sprawling out as far as 50-75 miles from the centers of metropolitan areas.

First, at least some will not find this an offensive vision provided that the necessary transportation infrastructure is in place to ensure reasonable cross region access and mobility. To some extent is this not the Randstad of the Netherlands with its multiple nodes and relatively super connective infrastructure, but the suggestion here is that this will be on a North American scale.

Second, with the Oregon or Washington land use provisions it will be necessary to greatly expand the development boundaries to encompass the development frame. Obtaining agreement from the outlying satellite cities and county governments to this end and, therefore, giving up local control over economic development and development decisions will be beyond the institutional capacity of most regions even with the help of state growth control statutes.

Third, a grand metropolitan wide government might be established to manage the region. This is unlikely given that the few metropolitan government experiments have been limited to no more than the core county of the region, e.g., Indianapolis or Nashville. Further, no metropolitan government experiments have been initiated in the last 20 years.

Finally, cooperative arrangements could be adopted but this seems improbable given that even with state statutory help in Oregon, Portland’s attempt at focusing growth seems doomed because the growth boundary will not be nearly extensive enough to accommodate satellite city development that appears to be inevitable as technology continues to make decentralization ever more attractive. This is the same problem that the Netherlands has experienced in its continuing difficulty in developing an appropriately decentralized management structure for the nodal interactions of the Randstad and its peripheral regions. This is in the context of a 100 year development rather than the more rapid and chaotic development we have seen in North America. Perhaps the most that can be hoped for in the near future is that some of the outer region counties where new centers are formed will adopt provisions to set aside some land for uses other than development.

3. Modeling.

Starting from the above analysis, we present hereafter two models relating. to the phenomenon addressed: one is a model of (household) residential choice, the other a model of (peri)urban development resulting from such choices.[6]

3.1 Model 1: residential choice.

Assume a well-behaved utility function with as arguments a general good, q, three possible residential choices (central city, x_1, suburbs, x_2, edge cities, x_3) and leisure, 1 :

$$u (q; x_1, x_2, x_3; l) \qquad (1)$$

The constraints for the maximizing process are the following :

		(Dual variables)
$pq + p_1x_1 + p_2x_2 + p_3x_3 + \pi l = r^*$	(2)	λ
$tq + t_1x_1 + t_2x_2 + t_3x_3 + \tau l + t^*$	(3)	μ
$x_1 + x_2 + x_3 = 1$	(4)	ρ
$x_i = x_i^2$, $I = 1,2,3$	(5)	σ_i

(2) is the budget constraint, (3) the time constraint, (4) the residential exclusivity constraint, and (5) the binary constraint.

Consider now the first order condition for x_3; it can be written as :

$$x_3 = ½ + (u'_3 - \lambda p_3 - \mu t_3 - \rho) / 2\sigma_3 \qquad (6)$$

where x_3 should be either 0 or 1 (σ_3 guarantees that). One supposes u'_3 to be much larger than u'_2 or u'_1, and further a sudden drop in p_3 (which includes also transportation and discounted moving costs) and t_3, due to "cyberspacing"; in such a case x_3 = 1 could supersede x_1 and x_2 as non-zero candidates.

The following example shows this.

Let the utility function. be :

$$u = q + 2x_1 + 2.5x_2 + 4x_3 + l \qquad (7)$$

and the prices and unit time requirements

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[6] For a previous approach along the same lines, one is referred to Jean H.P. Paelinck, 1983, *Formal Spatial Economic Analysis*, Gower, Aldershot, chapter 4.

p=l, $p_1=1$, $p_2=2$, $p_3=5$ or 3, $\pi=3$ (8)

$t=2$, t,=l, $t_2=2$, $t_3=5$ or 3, $\tau=1$ (9)

Table 1 hereafter synthesizes the results of the optimization process:

Table 1.[7]

	u	λ	μ	ρ	σ_1	σ_3
$x_1=1$	9.2					
$x_2=1$	8.9					
$x_3=1$ with $p_3=t_3=5$	9.0					3.5
$x_3=1$ with $p_3=t_3=5$	9.6					-7.0
			.6	.2	.9	.3

So in the pre-cyber phase x, is the optimal residential choice; it becomes x_3 with the reduction in p_3 and t_3.

3.2 Model 2: resulting urban development.

This development has been modeled taking into account the previous result and introducing the following explicit assumptions:

A, : there are three groups of workers, non-qualified (a), qualified (b) and potential "cybermen" (c); their increase is proportional to total increase in urban active population, with coefficients a,, α_b and a, totaling one.

A_2 : activity (in terms of employment) is attracted to the urban area as a function of the presence of b- and c-workers, with coefficient β.

A_3 : a-workers locate in the central city (zone 1).

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7 In fact, one of the type-(5) equations is superfluous, as two of them, together with (4), guarantee remaining binarity.

A_4 : b-workers locate in the central city below a critical density, then move out to the suburbs (zone 2; coefficient y).

A, : c-workers locate in the central city below a still lower critical density (coefficient δ), then move out to the suburbs (fraction ϵ) and the edge cities (zone 3; fraction I- E); if already in the suburbs they move out above a critical density to the edge cities (coefficient ζ).

A_6 : activities locate in the central city as a function of available b- and c-workers (coefficient θ), otherwise in the edge cities.

A_7 : activities are further attracted in zones 1 and 3 above a certain threshold level, and moreover they cross-influence each other (**coefficients** κ and v).
The resulting model presents itself as follows, dots above variables symbolizing time differentials; P = (active) population, Q = activities.

$\dot{P}_{a1}$		$\alpha_a\beta$	$\alpha_a\beta$	$\alpha_a\beta$	$\alpha_a\beta$	$\alpha_a\beta$	0	0		P_{a1}	0
$\dot{P}_{b1}$	$-\gamma$	$-\gamma$	$-\gamma$	0	0	0	0	0		P_{b1}	$\gamma\pi_1^*$
$\dot{P}_{c1}$	$-\delta$	$-\delta$	$-\delta$	0	0	0	0	0		P_{c1}	$\delta\pi_1^{**}$
$\dot{P}_{b2}$	γ	$\gamma+\alpha_b\beta$	$\gamma+\alpha_b\beta$	$\alpha_b\beta$	$\alpha_b\beta$	$\alpha_b\beta$_	0	0		P_{b2}	$-\gamma\pi_1^*$
=											+
P_{c2}		$\epsilon\delta$	$\epsilon\delta$	$\epsilon\delta$	$-\zeta$	$-\zeta$	0	0	0	P_{c2}	$\zeta\pi_2^{**}-\delta\epsilon\pi_1^{**}$
$\dot{P}_{c3}$	6(1-E)	6(1-E)	6(1-E)	$\zeta+\alpha_c\beta$	$\zeta+\alpha_c\beta$	$\alpha_c\beta$	0	0		P_{c3}	$-[\delta(1-\epsilon)\pi_1^{**}$ $+\alpha_c\beta$ + a $+\zeta\pi_2^{**}]$
$\dot{Q}_1$		0	θ	θ	0	0	0	κ	$-\nu$	Q_1	$-\kappa Q_1$ [illegible]
$\dot{Q}_3$		0	$\beta-\theta$	$\beta-\theta$	β	β	β	$-\kappa$	ν	Q_3	$\kappa Q_1^*-\nu Q_3^*$

This can be condensed as system :

$$\dot{y} = A\,y + a \qquad (11)$$

Matrix (10)22 has a quasi-triangular structure; the **coefficients** responsible for possible complex eigenvalues (leading to cyclical behavior of the system) are $\alpha_a\beta$ (location of a-workers in the central city), γ (departure of b-workers from the city center), $\alpha_b\beta$ (location of b-workers in the suburbs), and κ and v (activity attraction and repulsion).

Next step is to simulate system (1 0)-(11); Table 2 proposes the following values :

Table 2.

Coefficients	Values
α_a	.1
α_b	.6 or .4
α_c	.3 or .5
β	.01
γ	.1
δ	.1
ϵ	.1 or .5
ζ	.1
θ	.005 or .002
κ	.001
ν	.001

Table 3 suggests initial values and critical levels.

Table 3.

Variables	Values
P_{a1}	30
P_{b1}	15
P_{c1}	15
P_{b2}	5
P_{c2}	5
P_{c3}	0
Q_1	70
Q_3	0
π_1^*	50
π_1^{**}	30
π_2^*	8
π_2^{**}	4
Q_1^*	80
Q_3^*	0

Matrix A and vector a from (11) then turn out to be :

A=

0	.001	.001	.001	.001	.001	0	0	
-.1	-.1	-.1	0	0	0	0	-0	
-.1	-.110	-.	0	0	0	0		
.1	.106	.106	.006	.006	.006	0	0	
.1	.104	.104	.004	.004	.004	0	0	
.01	.01	.01	-.1	-.1	0	0	0	
.05	.05	.05	-.1	-.1	0	0	0	
.09	.093	.093	.103	.103	.003	0	0	
.05	.053	.053	.103	.103	.003	0	0	[8]
0	.005	.005	0	0	0	.001	-.001	
0	.002	.002	0	0	0	.001	-.001	
0	.005	.005	.01	.01	.01	-.001	.001	
0	.008	.008	.01	.01	.01	-.001	.001	

a' = [0 5 3 -5 { .5 , -.7 } { -3.5 , -2.3 } - .08 .08]

System (11) will be simulated along those lines.[9]

Figure 1 hereafter presents results of simulating the standard system, i.e. the first row of the alternatives in matrix A and vector **a**.[10]

There is perfect consistency between activities, expressed in number of jobs occupied and active population present in the urban-suburban-edge area. Except for this consistency check, the

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[8] Only combined with a, = .3.

[9] With thanks to Peter Arena and Raj Kulkarni for computational assistance.

[10] The order of the letters corresponds to the order of the endogenous variables in table 3.

coefficients have never been altered to obtain Figure 1.

It shows :

- a constancy of non-qualified workers and total activity in the city center;

- an increase in qualified workers, and a dramatic decrease of “cyberworkers” in the same central city;

- a stability of “cyberworkers” in the suburbs, and a decrease of qualified workers (“back to the city center”!);

- an increase of “cyberworkers” and of total activity in the edge cities.

These results match the ones obtained in section 2.

Other simulations have been performed; for instance Figure 2 shows the results of using options $P_{c2}(2)$, $P_{c3}(2)$, Q,(2) and Q,(2), the main substitution observed being P_{c2} vs P,,.

The latter option has also been simulated as a generalized Lotka-Volterra model”, i.e.

$$\dot{y} = \hat{y} (A y + a) \qquad (12)$$

Qualitatively the results are similar (Figure 3), except for some “enlarging” and “squeezing”, which is the result of the presence of the multiplicative vector y, so the linear version seems to be more adequate in this case.

4. Conclusions.

This paper develops the hypothesis that urban growth and relocation in the U.S. metropolis will be concentrated in centers far beyond the current “edge city” dominated periphery. While a number of contributing factors are identified, computer integrated communications technology is seen as the newly emerging factor that will induce the hypothesized outcome. While some supporting evidence is cited it is insufficient to fully support the type of decentralization that is described. a residential choice and a related urban

[11] On generalized Lotka-Volterra specifications, see J.H.P. Paelinck, Contributions récentes aprts vingt ans d’économétrie spatiale, ***Revue*** *européenne* ***des sciences*** *sociales,* Tome XXVII, No 88, pp. 6-10).

development model were developed to examine the hypothesis with numerical analysis. The results support the hypothesis about the future changes in U.S. metropolitan geographic form.

Numerical experiments are similar to simulations and, therefore, are not substitutes for empirical evidence. However, the assumptions upon which the models are erected are quite plausible and, therefore, must be viewed as lending support to the hypothesis or thesis of this paper. Nonetheless, future empirical research is needed to test the hypothesis and the related models.

Figure 1

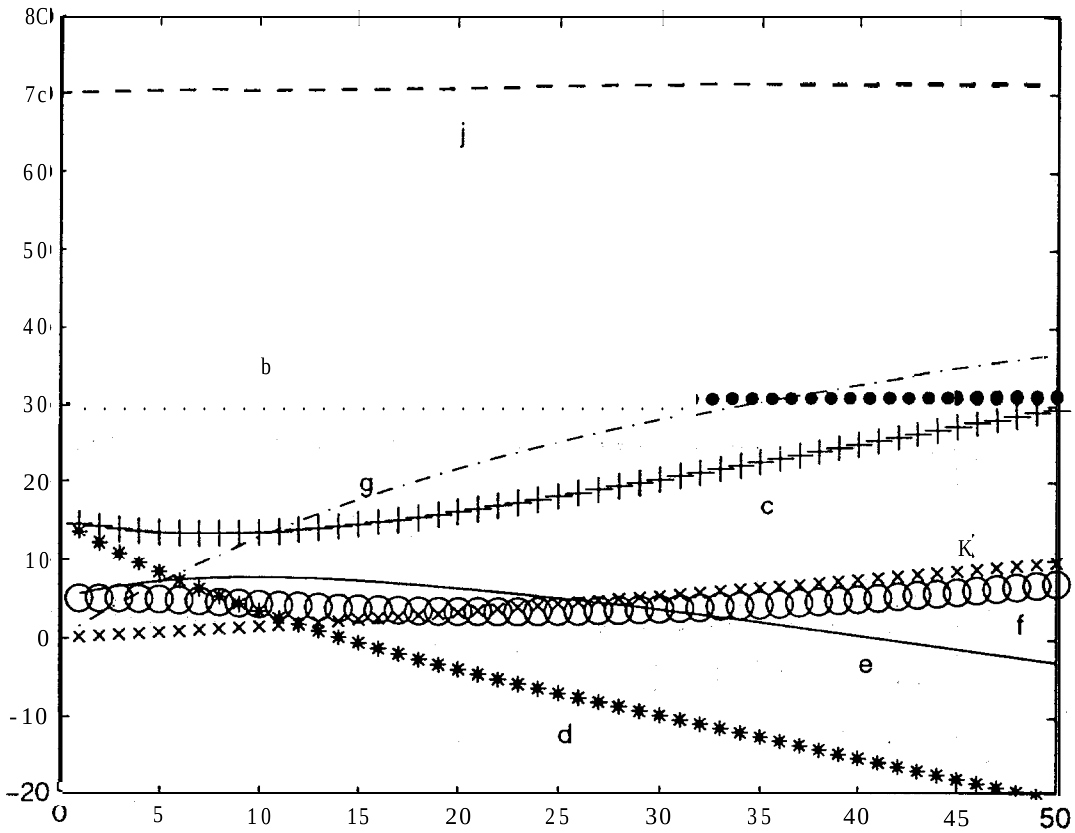


Figure 2

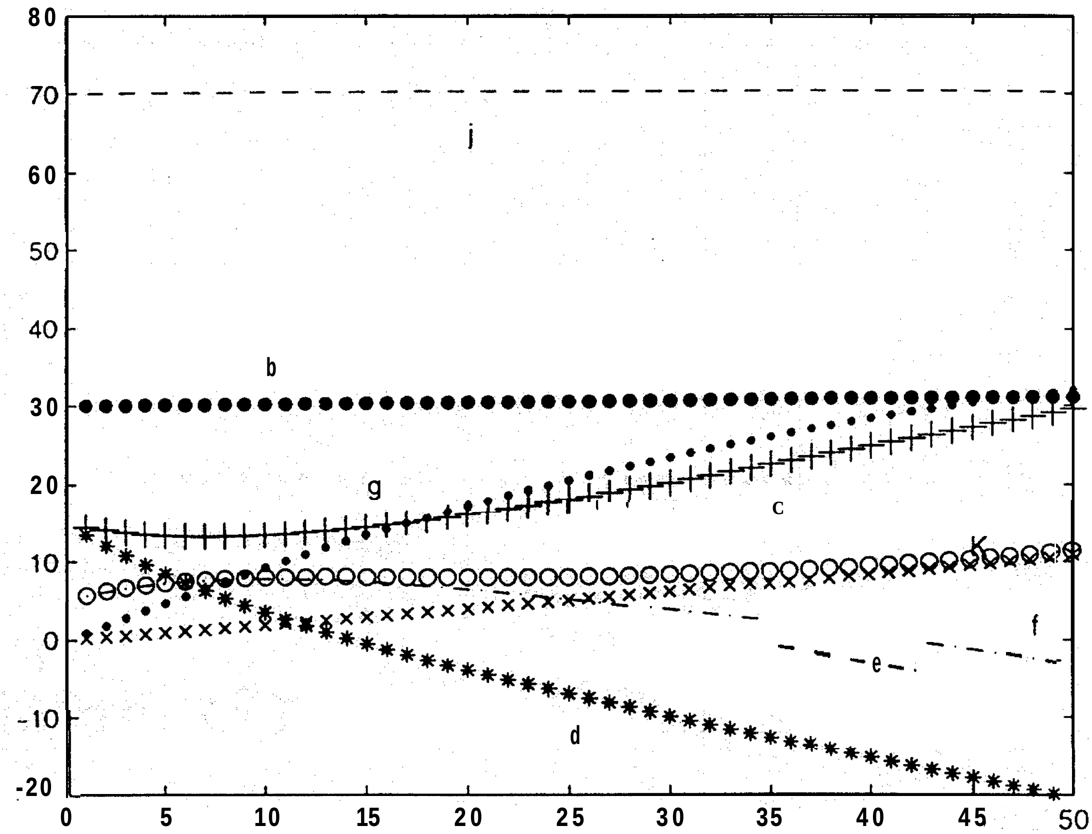
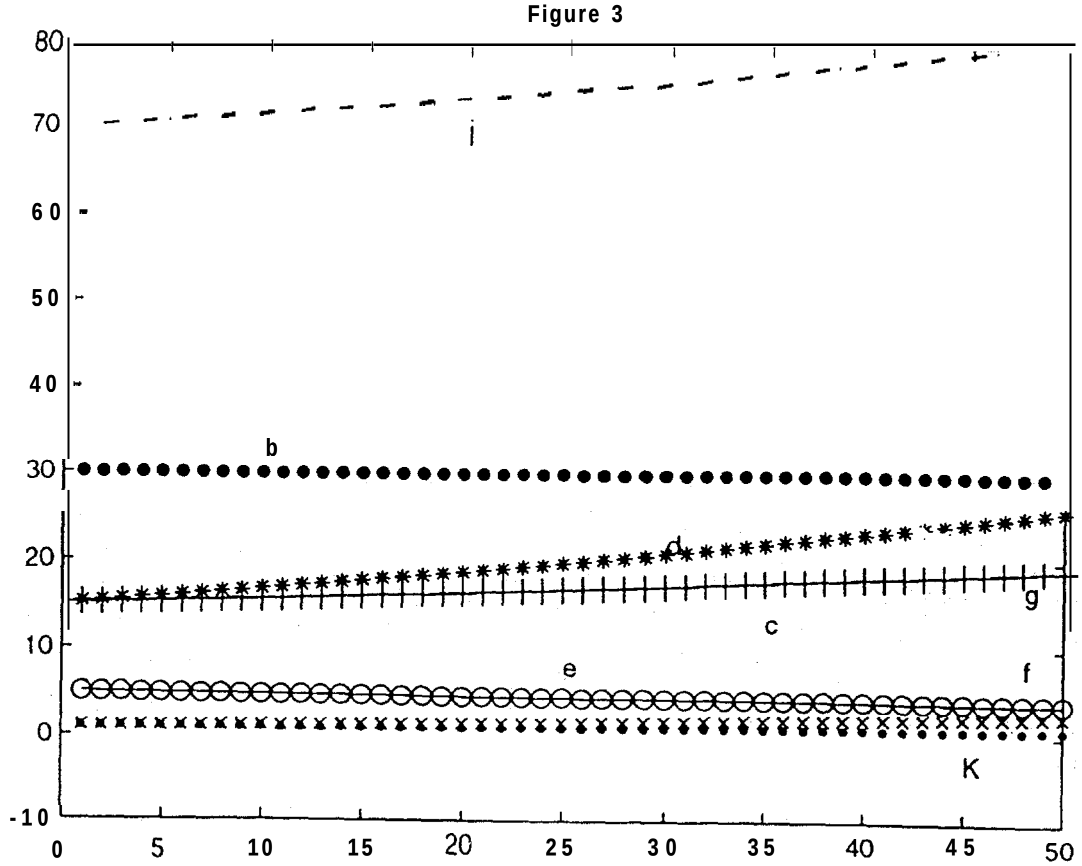


Figure 3



FACTORS FOR THE STUDY OF LONG-TERM IMPACTS OF TELECOMMUTING AND INTELLIGENT TRANSPORTATION SYSTEMS ON RESIDENTIAL AND BUSINESS LOCATION CHOICE

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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, 199 1). 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 kilometers 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.

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):

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).

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:

$$U_i^{RP} = \beta' x^{RP} + \alpha' y^{RP} + \epsilon \tag{1}$$
$$= V_i^{RP} + \epsilon$$

SP model:

$$U_i^{SP} = \beta' x^{SP} + \gamma' z^{SP} + \nu \tag{2}$$
$$= V_i^{SP} + \nu$$

$$\mathrm{Var}(\epsilon) = \mu^2 . \mathrm{Var}(\nu) \tag{3}$$

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
α,β,γ= vector of unknown parameters
ϵ,ν= 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 ϵ and ν 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, ϵ and ν) 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 β 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, ϵ and $\mu\nu$ 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:

$$\mu U_i^{SP} = \mu\beta' x^{SP} + \mu\gamma' z + \mu\nu \tag{4}$$

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.

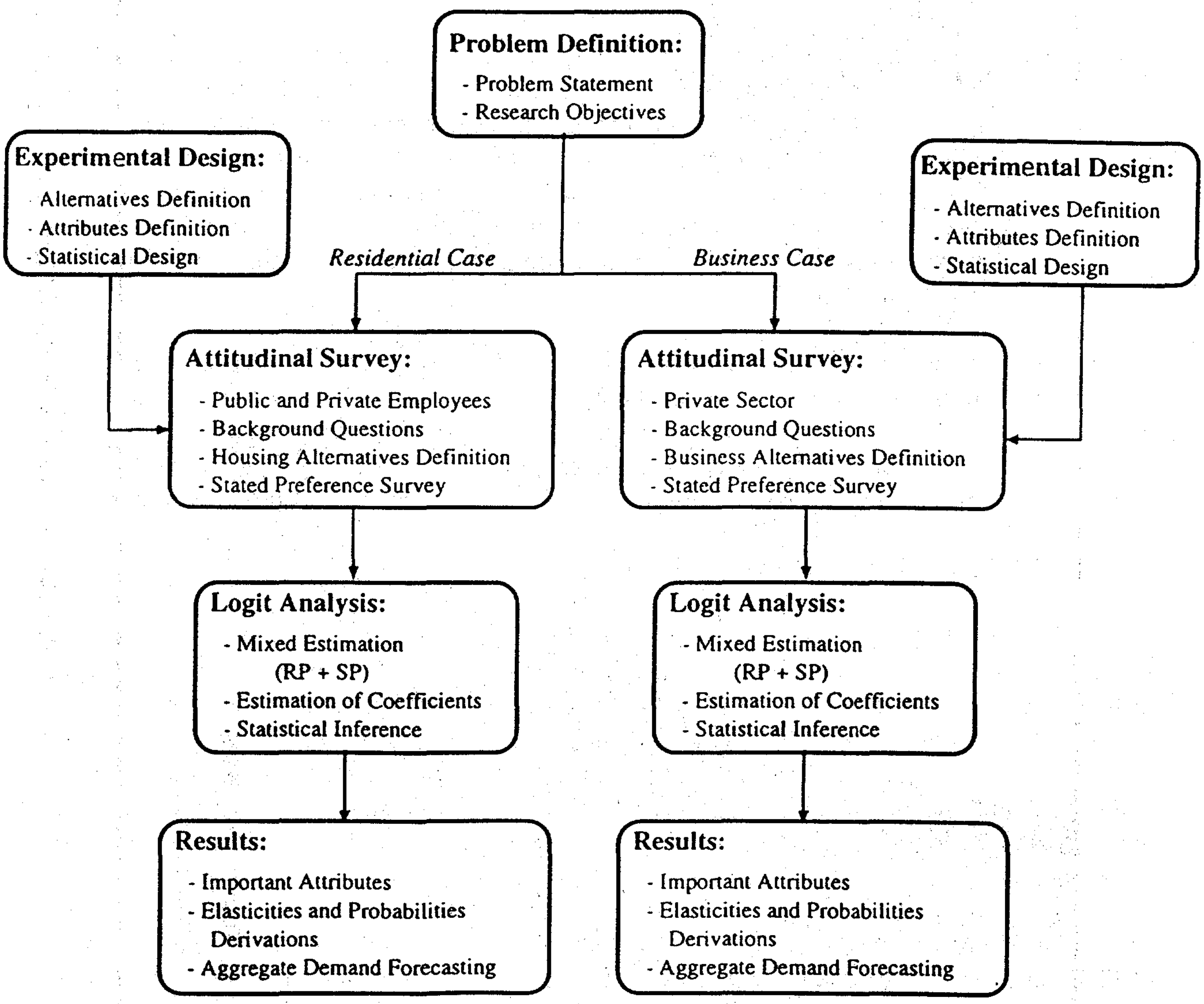

Fig. 1. Research Framework

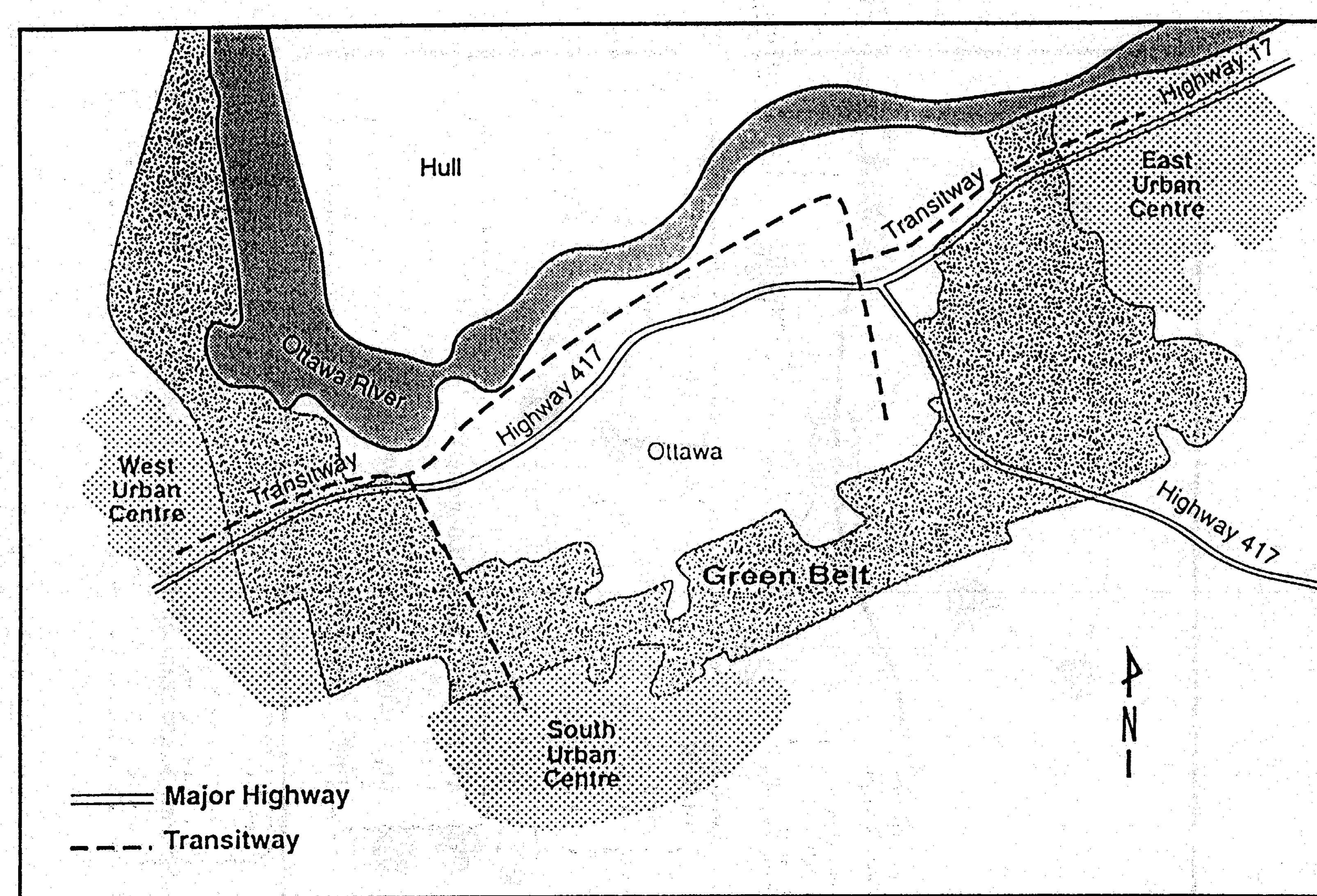

Fig. 2. The Study Area within the RMOC, Ontario, Canada

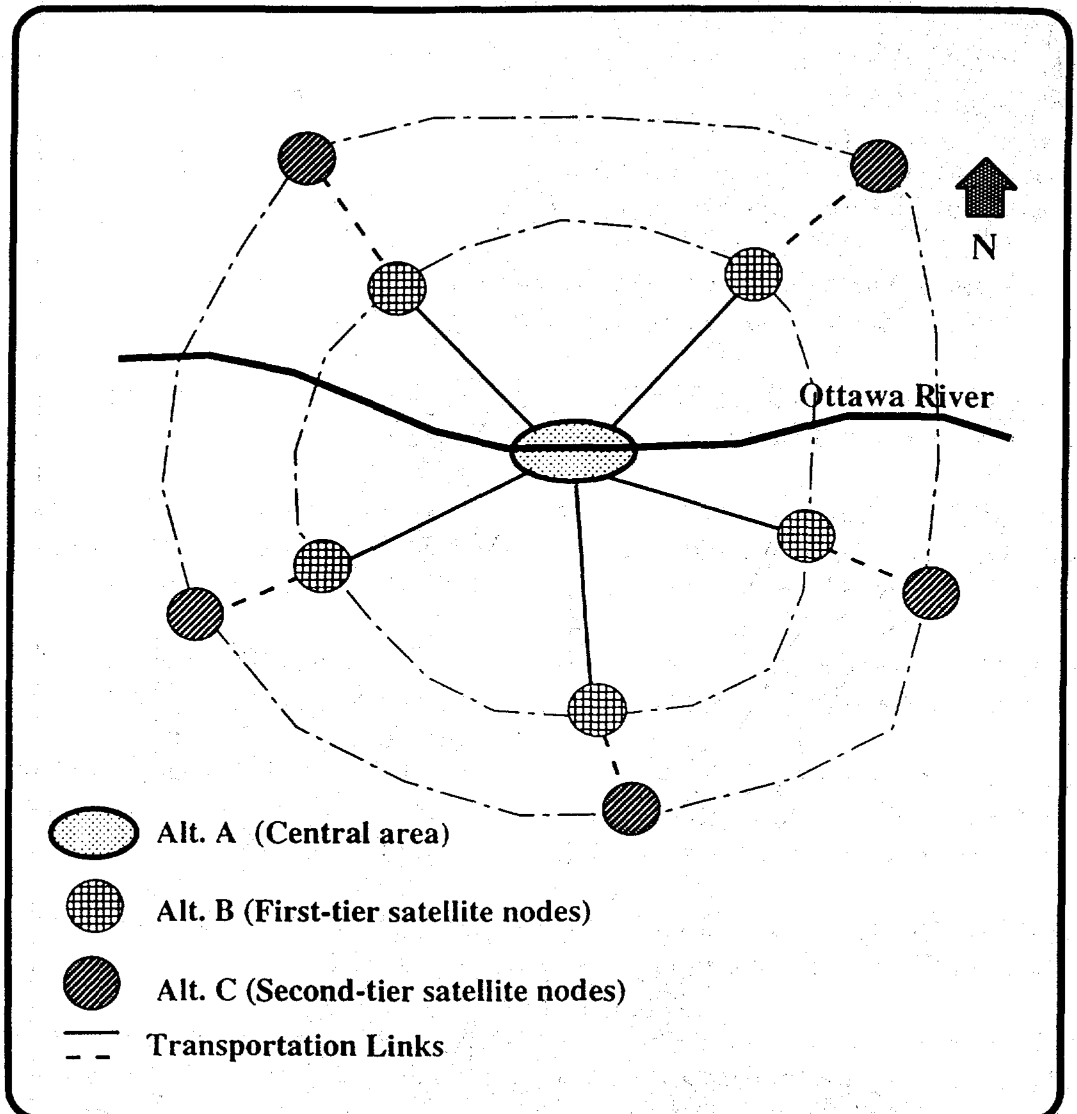

Fig. 3. Schematic Diagram of Housing and Business Location Alternatives

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