

## **MAPPING THE TERRAIN OF INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT) AND HOUSEHOLD TRAVEL**

Working draft, comments welcome.  
November 2002

Kevin J. Krizek \* and Andy Johnson  
Urban and Regional Planning Program  
University of Minnesota  
301 19<sup>th</sup> Ave S.  
Minneapolis, MN 55455  
Phone: 612-625-7318  
Fax: 612-625-3513  
Email: [kjkrizek@umn.edu](mailto:kjkrizek@umn.edu) and [ajohnson@hhh.umn.edu](mailto:ajohnson@hhh.umn.edu)

\*Corresponding author

6,745 words + 1 table + 2 figures = 7495

### **ABSTRACT**

New forms of information and communications technology (ICT) are emerging as primary forces influencing people's daily activities. Published work to date, however, has been pursued from a variety of perspectives, studying different phenomena that are published in a variety of venues. With such disparity of topics and perspectives overlaid on rapidly changing use of ICT, it is difficult for the researcher to keep abreast of recent developments in knowledge. This paper serves two primary purposes using a literature search as the primary means of inquiry. It first maps the terrain of existing work to date related to ICT and household travel and identifies the predominant nature of existing study—conceptual or empirical—as well as voids in the existing knowledge base. Second, the paper sheds light on emerging phenomena to help conceptualize future research by identifying and describing three dimensions by which future work should be understood: (1) the purpose of the activity (e.g., subsistence, maintenance, discretionary), (2) the effect on travel (e.g., substitution, modification), and (3) the role of sub-tasks (browsing vs. purchasing). This paper will help serve as a blueprint to help conceptualize future research and detailed lines of inquiry relating ICT and household travel.

## INTRODUCTION

New forms of information and communications technology (hereafter ICT) continue to emerge as primary forces influencing people's activities and travel. More than a century ago, for example, the telephone was instrumental in establishing new patterns of both communication and shopping. Rural residents, in particular, were now able to purchase products through catalogues (e.g., Sears) and have them delivered to their outlying locations. Later in the century, the energy crisis of the late 1970's prompted increased attention on reducing travel and the potential role of emerging forms of computer assisted communication. Major employers gravitate to telecommuting as a strategy that would provide employee flexibility and increase the array of services offered. Similar themes, albeit somewhat modified for current settings, continue to be the topic of attention as researchers and futurists examine the influence of rapidly changing forms of information technology on society. The blossoming popularity of the internet has now placed e-commerce front and center on the minds of many. Burgeoning forms of computing communication (e.g., personal data assistants, cell phones) permeate even the simplest of transactions.

But what is the likely impact of these new forms of information and communication on household activity? What is their potential in eliminating, reducing or modifying travel? The effect of technology, and more specifically, ICT is a topic that has been studied on a number of levels in previous work. For example, Edwin Parker [1] estimated that the introduction of computers and telecommunications will change modern economics as "information" cannot be treated as a commodity. Later Alvin Toffler [2] surmised that ICT improvements will in fact make cities obsolete, while Lehman-Wilzig [3] projected that telecommunications might eliminate all travel. More recently, others have provided exposes relating technology to contemporary urban life or policy agendas (e.g., Smart Growth) [4, 5]. Interests in ICT remain varied. These include geographical perspectives aiming to examine the loosening of spatial and temporal linkages to psychological perspectives aiming to uncover ways in which ICT changes communication patterns to economic analysis of increasing the efficiency of freight delivery.

A perspective receiving considerable attention, and one that is at the heart of this paper, relates to the influence of ICT on household travel. Motivation for interest in this specific topic remains varied. For example, employers may be interested in enhancing employee flexibility, reducing overhead costs, improving operational efficiency and minimizing time spent in travel for their employees. Commercial businesses are interested in providing options for customers to not travel. The most publicized interests are those who look to ICT to save energy, reduce congestion, and improve air quality. A premise of such interest rests on the likelihood that ICT will reduce the need for automobile travel (either in terms of vehicle miles traveled (VMT) or number of vehicle trips). Particular attention focuses on the potential of ICT to eliminate, reduce, or temporally shift peak-period commute travel. But interestingly enough, while deployment of ICT has skyrocketed in recent years, overall household travel in terms of distance and/or trips has increased as well. This suggests that our knowledge of relationships between ICT and travel, while growing, is still tentative at best.

The work that has been pursued to date on this subset of the ICT literature is varied. One only needs to refer to previous reviews [see, for example, 6, 7, 8] to gain a better understanding of the central questions and range of issues associated with this general line of inquiry. But these reviews are limited in at least two contexts. First, the bulk of previous literature focuses on one aspect of ICT: affecting the work commute (hereafter telecommuting). This aspect has, admittedly, been the focus of most activity and development. But everyday use of ICT has migrated well beyond the bounds of affecting only the work commute. As Golob claims, "we must do better than that [focusing on telecommuting] in order to keep our field relevant to planning and policy making" [7]. Secondly, technology is rapidly changing and so is the use of it by individuals and households. It is necessary to keep abreast of recent developments, grapple with the emerging ranges of issues, and understand current work about these developments.

In response to at least these two calls, this paper uses a literature search as the primary means of inquiry to update our knowledge of central issues related to ICT. It uses existing study to help frame and update a task that has been the target of a previous "research needs assessment" presented for TRB in 2000 [9]. In doing so, this work first maps the terrain of existing work to date related to ICT and household travel. It identifies the predominant nature of existing study—conceptual or empirical—and identifies voids in the existing knowledge base. Second, the paper sheds light on emerging phenomena to help conceptualize future research. This review therefore serves to update our knowledge about a body of knowledge that is undergoing quick changes. It is hoped that it will help serve as a blueprint for more detailed lines of inquiry related to ICT and household travel.

Before we begin it is important to frame the issues covered in this review. The present discussion is limited to understanding the behavior of households and individuals relative to different dimensions of ICT, broadly referred

to telecommunications or information technology in some circles, and ICT in others. We use the term ICT because it encompasses a variety of terms describing a wide array of communication/technological enhancements. The most commonly cited examples include Internet improvements (i.e., broadband, e-mail, increased electronic accessibility to information and opportunities, more powerful personal computers), cell phones, ATMs, and teleconferencing. ICT is about using computers to work at home and cell phones to arrange a meeting place remotely. It is about ordering gifts on line and using internet availability to enhance home-schooling. It is about ordering an on-demand movie and using video-conferencing. This paper, however, is not about reviewing some of ICT's other impacts. It is less about the use of Global Positioning System (GPS), Advanced Vehicle Transportation Systems (AVTS), the general nature of Intelligent Transportation Systems (ITS), and the impact of ICT on commercial vehicle operations or business to business commerce. The focus in many of these categories is more on modifying or managing travel than replacing it. Our focus here lies in how ICT may affect the travel patterns of households and/or individuals.

## **PART I) PREVIOUS RESEARCH**

### **Defining a Framework for Discussion**

Our review uses three dimensions to map recent literature of relationships between ICT and travel. The first dimension specifies whether the study is conceptual or empirical in nature. This matter is relatively self-explanatory; the former describes theoretical arguments or key relationships, while the latter measures behavior related to ICT and travel. The second and third dimensions are based on, respectively: (a) the purpose of the specific activity being studied and (b) the effect that ICT has on travel. These two dimensions and the effect that ICT has are briefly described below. The literature is then mapped and discussed using this framework.

#### *Purpose of the ICT Activity*

A critical aspect relates to nature of activities that are being pursued using ICT. For example, previous study has classified eight activities in which telecommunications can be substituted for travel (telecommuting, teleconferencing, teleshopping, telebanking, tele-entertainment, tele-education, tele-medicine, and tele-justice) [10]. This list presents a healthy list of ICT applications; but being more than a decade also, it is one that has undergone much change in recent times. Rather than attempt to identify each of the ever growing list of ICT applications, we find value in using relatively broader classification scheme—one that is also useful in helping us better understand how ICT relates to a household's overall travel. The typology we adopt is based on work first introduced by Reichman [11] who defined three major classes of travel-related activities. These three classes represent:

- *subsistence* activities, consisting of activities that generate income, including work, business services, and sometimes schooling (travel associated with this activity is most commonly commuting),
- *maintenance* activities, consisting of the purchase and consumption of convenience goods or personal services needed by the individual or household, and
- *leisure or discretionary* activities, comprising multiple voluntary activities performed on free time, not allocated to work or maintenance activities.

This typology of activities has been employed by Pas [12, 13] and Bhat and Koppelman [14] to classify daily travel activity behavior. Such a framework also represents the cornerstone of current activity-based transportation modeling efforts (e.g., TRANSIMS) currently underway [15-24]. We feel that this classification is directly applicable to this line of inquiry as it provides a parsimonious strategy to map the demand for central purposes of ICT activity (e.g., working versus banking versus shopping) and the degree to which existing study has tended to focus on one or more of these aspects.

#### *The Effect of ICT on Travel*

Almost 20 years ago, seminal work on ICT and travel by Salomon provided a foundation that helped outlined basic types of interaction [8, 25]. These types of interaction—substitution, modification, enhancement, and neutrality—have been employed in subsequent discussion and analysis [10, 26, 27] and we employ them as a means to better understand the theories and evidence of past research.

- *Substitution* of travel refers to the elimination of trips, trips that are no longer required as a result of ICT improvements. This interaction has been the focus of most of the ICT literature, and the substitution of subsistence trips, by definition, is a phenomenon inherent in the term telecommuting [7]. While the substitution hypothesis is one that holds great hope by many, the scale to which this is happening is estimated to be quite smaller than originally anticipated [10].
- *Modification* refers to travel that is likely to be altered, primarily by a shift in the timing and routing of trips (spatial and/or temporal transformations). It may also refer to the manner in which trips are linked together (i.e., trip chaining) or even the mode of travel. The benefits of shifting even a small amount of peak hour travel to different times (through telecommuting) are mentioned as a key strategy for reducing levels of

congestion. The literature agrees that ICT will modify travel behavior [28-30] but the lack of consensus of in what way is a sub-topic that is outstanding.

- *Generation* refers to any generation of travel that would not have occurred but for the existence of ICT. Little is known about how ICT may generate additional traffic, primarily due to the difficulty in determining causality and a lack of time-series data before and after ICT enhancement and deployment.
- *Neutrality* refers those instances in which ICT has no foreseeable effect on household travel behavior.

### Mapping the ICT Literature

Our mapping of recent work (Table 1) reviews over 50 studies to understand the nature and orientation of existing work. We classify each study first as being *primarily* conceptual or empirical in nature. The second mapping dimension used in Table 1 considers the primary nature of the work—its relation to subsistence, maintenance or discretionary travel. The purpose of this table and subsequent discussion is to help identify where existing research is concentrated and where future research would most usefully be targeted.

#### *Subsistence*

Subsistence activities, when viewed relative to ICT, refer to individuals working at home or other remote locations, most often with telecommunications links to a central office. Interest in telecommuting stems from the heralded potential of relieving peak hour traffic congestion through reducing or modifying people's work trip (on average, considered to comprise one-third of all household travel). The widespread availability of telecommunications services, combined with the use of such services, has been the principle reason this aspect of ICT has been the target for the overwhelming majority of all study of ICT use [10, 30, 33-36, 39, 40, 42, 44, 45, 47]. Additional reasons for the focus on this line of work are two-fold. First, transportation planners and modelers have long been preoccupied with the work commute (often considered the lion's share of household travel). Secondly, work related activities are typically "cleaner" to analyze than maintenance and discretionary activities because they are typically more stable and predictable.

But despite the telecommuting piece of the ICT puzzle being subject to the most mature models and conceptual frameworks, there is much variation in its orientation. For example, previous work has focused on different dimensions of the issue, such as defining telecommuting [32], forecasting telecommuting, [36, 37] understanding individual and employer attitudes toward telecommuting (e.g., flexible working arrangements, increased proliferation of self-employment) [33-35], and land use implications [48, 49, 68]. Mokhtarian [36] has attempted to assemble the substantive findings to date under a unified framework by examining current knowledge in forecasting the demand for telecommuting and the resulting transportation impacts.

The culmination of this line of work has, however, yielded somewhat conflicting findings. Some have found that telecommuters reduce their number of trips and distance traveled on net travel [see 36 for other reviews, 46], on just telecommute days [29, 30, 54] or on just non-telecommute days [29, 54]. Other work has uncovered anecdotal and empirical evidence suggesting travel stimulation or generation [6, 8, 10, 40], sometimes only on non-telecommute days. Some go so far as to hint that levels of traffic jams and congestion may heighten because it provides an opportunity to catch up with telephone messages and email [5].

#### *Maintenance*

The effect of ICT on maintenance travel has enjoyed perhaps the longest history of study. Researchers examined the impact of early telephone order (and delivery) businesses on the ease of rural living and the vitality of town commercial centers. Central tenets of this line of inquiry continue today with the advent of the internet and e-commerce permeating the simplest of maintenance transactions. These types of activities account for over half of all household trips (and 40 percent of personal miles travel), but there is a lack of knowledge about how they are affected by ICT. Some of the existing work is oriented towards the freight and delivery aspects of e-commerce [41, 64]. The bulk of the maintenance travel-related literature, however, focuses on shopping (as opposed to maintenance-type activities such as banking or paying bills).

More than a decade ago, Salomon and Koppelman provided a theoretical framework to understand home shopping [56] which was later supported with an empirical investigation [66]. While its preoccupation with telephone shopping limits the applicability of such work to a contemporary setting, this work continues to enlighten current study. An initial contribution they made was to distinguish between the act of shopping (the acquisition of information) and purchasing—a distinction of growing importance related to ICT activity. A second contribution is that they articulated five primary steps in selecting a piece of merchandise: (1) entry into the market, (2) choice among alternative shopping modes, (3) information gathering, (4) evaluation of information obtained, and (5) choice

between purchase, continuing to shop or exiting the market. In a contemporary expose, Couclelis [59] provides a more detailed breakdown of similar tasks (see itemized list in later section) that apply more aptly to ICT purchases.

Gould [22, 58] provided an overview of the transportation implications emerging from home shopping and on-line commerce. Her review focused on possible changes and demands placed on delivery services, the possibility of goods with no physical delivery, and the possible growth of new retail venues. She touched on a number of the difficulties in estimating the use of home shopping, including the need for understanding the different stages of shopping, attitudinal issues and opinions of consumers, and how ICT travel is related to other physical travel. Marker and Goulias [26] provide a framework for understanding and estimating the use of ICT and grocery shopping. In so doing, they outline salient issues as they relate to the likely effects on traffic (e.g., substitution, consolidating loads, trip chaining), forms of delivery, and methods in modeling such activities.

To our knowledge the most applicable empirical work on this issue is provided by Handy and Yantis [63]. They examined in detail the potential substitutability of three different types of activities: movie watching, shopping (non-grocery), and banking. These activities were chosen to represent the spectrum of nonwork activities from entertainment to personal business with movie watching at one end (discretionary), banking at the other (maintenance), and shopping somewhere in the middle. They conducted a household survey in three different cities to explore individual use of and choices about the each of the activities. Not surprisingly, their results suggest complicated relationships between in-home activities and those requiring out-of-home physical travel. For the most part, they found that out-of-home versions of movie-watching, shopping, and banking offer qualities that are not currently duplicated by the in-home versions.

Previous research on maintenance travel, while limited, has served to successfully identify salient dimensions for consideration. One issue that keeps emerging is that different goods have different potential for successful e-commerce. Gould [22] highlighted that consumers will make decisions based on the four primary costs related to shopping: the cost of the item, the cost of the time to search for the item, the time to travel, and the expense of travel. There also appears to be wide variation in how different products are perceived to be more or less convenient to purchase on-line. According to one survey, home electronics, computer hardware and software are the most convenient items to shop for online; clothing and apparel are the least [69]. Our responsibility as transportation behaviorists is to understand how these subtle nuances relate to household travel. Furthermore, consumers prefer using their senses for many types of shopping, for example trying on a shirt, smelling perfume, sitting in a chair. In-store shopping offers immediate gratification and social interaction [61]. Though, there seems to be consensus that significant potential remains for many other goods most notably books, music and movies (both downloaded and delivered), travel and theatre tickets, and computer software and hardware [61, 69].

### *Discretionary*

As evident in Table 1 the linkage between the use of ICT and discretionary activity is a topic that has received the least amount study. While the boundaries between maintenance and discretionary activity may blur (thus the cross listing of some of the studies in Table 1), at least two related thoughts come forward with respect to discretionary activity. The first refers to the inherently social and psychological needs of humans [25]. Much of the social interaction and human contact we require is invaluable and cannot be adequately served electronically. This need has important implications in how we spend our free time. The second consideration is that few discretionary activities (e.g., theaters, sporting events, pleasure shopping) can be replicated electronically. For example, renting a movie is not a substitute for going to the theatre because the two are usually not considered to be equivalent experiences. The latter usually provides a greater degree of social interaction and a higher quality product. This notion is reinforced in the Handy and Yantis study [63] which looked at home movie rental, television and theatre visits. Primary reasons for going to the theatre include the size of the screen, newer movies, better sound, getting out of the house and going out with friends that for many reasons cannot be duplicated without leaving the home. Both of these considerations suggest that in-home and electronic versions of goods and services are not likely to be viable substitutes for out-of-home and physical versions. For this reason, one should expect minimal travel savings (at best) with respect to reducing the roughly one-fourth of all discretionary trips currently completed.

A final issue for consideration relates to the idea that discretionary activity is not inelastic. It is likely affected by changes in the allotment of time to subsistence and maintenance activities. Salomon suggests that the increased leisure time resulting from increased efficiency from telecommuting results in increased leisure travel [25]. In other words, although discretionary activity itself may not be becoming electronic, as ICT makes subsistence and maintenance activity more efficient, people will have more discretionary time and subsequently travel more often.

## PART 2) TRENDS AND ISSUES FOR FURTHER RESEARCH

Having mapped the bulk of existing literature relating ICT and travel, the second part of this review combines that learned above with recent knowledge about how ICT is employed. The aim is to help articulate future lines of inquiry and topics for further research. This task is compounded by the rapidly evolving nature of ICT, both the manner in which it is employed and its availability. For example, online spending not surprisingly reached all time highs in the second quarter of 2002, up 41% from the previous year to 17.5 billion. Some predictions go so far as to suggest that online consumer spending will increase to over 70 billion this year [70], indeed a startling growth projection. On the contrary, some skeptics point to the still miniscule share of e-commerce (a mere 0.64 percent of all retail sales). There remains considerable uncertainty as to how this on-line spending will manifest itself, particularly as it relates to travel. Past failures of electronic home shopping have been documented [71]; one need look no further than the experience of Kozmo.com (the now defunct on-line delivery service for sundries who closed operations after only three years) to learn of the relative uncertainty associated with this line of service.

Online users amount to an estimated 98 and 140 million people in the country (between 34 and 50 percent of the U.S. population), [72] a number that is rising daily as Internet and other computer use becomes more deeply integrated into everyday patterns of behavior. In a similar growth phenomenon, there were over 128 million cellular phone subscribers by the end of 2001, up from 109 million in 2000 [73]. But again, the mere availability of technology does not necessarily mean it will influence travel. For example, an estimated 66 million American internet users say they are on-line “just for fun,” including sampling music, checking sports scores or electronic gaming [74]. This category probably includes the gathering of information (e.g., reading about news events). Such use may enhance one’s quality of life (by providing additional information or entertainment) but may have little role in affecting travel patterns.

The bottom line is that the research community is realizing that ICT affects different travel in different ways. We should not be surprised to see changes in one type of travel affect another type of travel. A breakdown that analyzes substitution, modification, generation, or neutrality for one travel purpose is just the tip of the iceberg. Some elements may substitute in one respect but enhance another. Similarly, looking at subsistence, maintenance or discretionary in isolation may be oversimplifying the effects we observe. To more clearly articulate some of these complexities, we provide Figure 1. This highlights three dimensions; the prism is used to represent how a comprehensive understanding of ICT and travel rests on knowledge from each leg. The x-axis dimension—purpose of travel—is one adequately defined above. The y-axis—effect on travel—is described in previous literature (and above), however, in a relatively superficial manner. Further discussion of the y-axis and the z-axis is provided.

### Effect on travel

A second dimension for inquiry relates to the specific effect that ICT is likely to have on travel. The principle effects—substitution, modification, generation, and neutrality—are well recognized in the literature and described above. These issues, however, constitute only one aspect of this dimension and travel is likely to be affected in ways broader and more detailed than just these four. It is important for us to understand the detailed behaviors that may be implied under each cover. Take for instance how behavior may likely be *modified* in the three examples provided below.

- Imagine the case of the teleworker, who is home during the workday and picks up groceries in the morning when the crowds are less (rather than on their typical route home from work). In this case, the substitution of the subsistence trip provides the flexibility pursue a temporal shift for a maintenance trip.
- Imagine the role that internet information would have in affecting the geographic distribution of where residents shop. Here the knowledge provided by ICT had an effect on the geographical distribution of where the individual shopped.
- Imagine how the time freed from on-line grocery shopping would allow increased time to sip coffee at the café. In this example we see how the substitution of maintenance travel increased the time spent in discretionary activities.

We quickly see the limits of the relatively simple substitution/modification taxonomy in understanding travel. Possible changes in mode of travel, trip chaining, trip making sequence, time of day are all considerations that should be on the radar screen for researchers in this area.

### Sub-tasks of the activity

The third piece of the ICT-travel puzzle is one that the research community is becoming increasingly aware of. Referenced above, it relates to the different ways in which ICT enters into sub-tasks associated with any given activity. Couclelis [59] provides greater detail on the general tasks outlined in Salomon and Koppelman [56] that tend to be associated with ICT and shopping for any but the most trivial of goods. These tasks include: (a) becoming

aware of need or want of a product, (b) gathering information about options, (c) searching and browsing, (d) seeking advise/expert help, (e) inspecting alternatives, (f) deciding on an item to be purchased, (g) deciding on a vendor, (h) purchasing a product, (i) tracking the status of an order, (j) getting an item to delivery point (e.g., home), (k) returning/exchanging an item, (l) seeking post-sales service. Only one of the tasks, purchasing the product, is commonly considered in analysis. (It is, after all, the task in which the important transaction takes place and also the one that is instrumental to the livelihood of bricks and mortar establishments.) While other tasks (for example, b, c, e, g, l) are recognized to be affected by ICT, a detailed and thorough understanding of nature of these relationships is not available.

For some endeavors, the availability of on-line information has already changed certain customs. The process of contacting governmental agencies or individuals, searching for housing, or pricing major purchases [74] are a few examples where internet use has started to eliminate the need for travel. It is now common practice to inspect the invoice price on-line prior to traveling to a single auto dealer to purchase a new car, a task in which it previously took stops at several dealers to get the best price. In this case “information gathering” has translated into travel substitution. But one must still be conscious of the fact that while ICT may help reduce travel associated with when acquiring information it may not necessarily reduce travel associated with the purchase of an item. It would be interesting to know what these activities are and any thresholds that might have been met that help make such activities more mainstream. As an effort to better clarify examples of future lines of inquiry relating ICT and travel, we provide Figure 2. In this figure each box represents an example activity for investigation. The manner in which the activity relates to two of the dimensions is represented by its placement in the box. The lighter shading (towards the right) is used to represent the degree to which ICT may be stimulating additional travel, much to the chagrin of many transportation planners.

When considering the role of ICT in completing subtasks a final matter stands out—differentiating between the population online buyers and online users. According to Jupiter Media of the 140 million online users, only 65 million (46 percent) are online buyers [72]. The most commonly cited reason for not being an on-line consumer is the risks associated with relaying credit card information over the internet [69]. While this population is forecasted to increase in upcoming years, the division is an important issue for consideration because it implies a considerable population may be browsing for information.

## **HURDLES AND CONCLUSIONS**

This paper serves two purposes to aid our understanding of how ICT and travel behavior relate. It first provides an up-to-date review of over fifty studies on the subject by mapping and discussing existing work across three dimensions. These three dimensions are the degree to which the study is (1) primarily conceptual or empirical in nature, (2) primarily addresses subsistence, maintenance, or discretionary activities, and (3) able to comment on the hypotheses of substitution, modification, generation or neutrality. The second contribution is that it identifies a framework and examples for researchers to use as a blueprint for future work on this subject.

As with any endeavor aiming to understand travel behavior, myriad difficulties exist. Before such difficulties can be overcome, they need to be identified, however. Below, we identify some of these hurdles, some of which have been introduced in previous study [25, 27, 58, 63]:

- Technologies that are widely promised for the future prove infeasible or are replaced by the next great technology before they have a chance to be adopted for mainstream use;
- The increasing familiarity of technology by children and other youth will likely have longer lasting impacts;
- The need for uncovering and understanding the various ways in which individuals use different forms of technology (e.g., browsing versus purchasing);
- Separating subsistence from maintenance and/or discretionary travel—they are often times intricately related (for example, a decrease in subsistence travel will likely result in an increase in other travel [25]). Teasing out the effect of one is likely to tell on part of the picture;
- The interactions between different types of travel are likely to be different in various contexts. There are also methodological problems in measuring them [25];
- More extensive time use (and activity based travel) analysis is required to determine how time freed from using ICT might be used in other activities;
- The potential for cross-substitution between different types of activities (e.g., substitution of surfing the internet for watching television);
- Dramatic variation across households (access to educational and financial resources often determine the degree to which ICT influence household behavior).

The study of ICT and travel is complex and challenging—though one that provides several avenues for investigation. This task is one that has been best described by Mokhtarian [9]:

“against the slower moving demographic and organizational changes that may be occurring naturally, the highly volatile technological environment and attendant consumer response speed up some of these natural changes and bring about entirely new ones...Thus improving our understanding of these processes is a moving target, and no sooner do we think we have made progress in answering one question then we realize that the question has been rendered obsolete or unimportant in environmental shifts.”

The work spotlighted in this review relates to only one piece of the ICT puzzle—that of household travel). This is, however, an important piece and one receiving more attention. As congestion, auto-reliant travel, and centrifugal forces of development continue to rise, researchers, modelers, and policy officials are likely to demand more detailed understanding of ICT’s role in tackling such phenomena. Several avenues and courses of study are needed to help uncover such phenomena; we hope this work helps in providing a roadmap to do so.

## REFERENCES

1. Parker, E.B., *Social Implications of Computer/Telecoms Systems*. Telecommunications Policy, 1976. **1**: p. 3-21.
2. Toffler, A., *The Third Wave*. 1980, New York: Bantam Books.
3. Lehman-Wilzig, S., *Will Cities Become Obsolete?* Telecommunications Policy, 1981. **5**: p. 326-328.
4. Mitchell, W.J., *Electronic Cottages, Wired Neighborhoods and Smart Cities*, in *Smart Growth: Form and Consequences*, T.S. Szold and A. Carbonel, Editors. 2002, Lincoln Institute of Land Policy: Cambridge, MA. p. 66-81.
5. Moss, M.L. and A. Townsend, *How Telecommunications Systems Are Transforming Urban Spaces*, in *Cities in the Telecommunication Age: The Fracturing of Geographies*, J.O. Wheeler, Y. Aoyama, and B. Warf, Editors. 2000, Routledge.
6. Mokhtarian, P.L. and I. Salomon. *Emerging Travel Patterns: Do Telecommunications Make a Difference*. in *Recent Developments in Travel Behavior Research*. 1997. Austin, TX: Oxford.
7. Golob, T.F., *Travelbehaviour.com: Activity Approaches to Modeling the Effects of Information Technology on Personal Travel Behaviour*, in *Travel Behavior Research, The Leading Edge*, D. Hensher, Editor. 2001, Elsevier Science/ Pergamon: Kidlington, Oxford. p. 145-184.
8. Salomon, I., *Telecommunications and Travel Relationships: A Review*. Transportation Research A, 1986. **20**(3): p. 223-238.
9. Mokhtarian, P.L., *Telecommunications and Travel*, in *Transportation and the New Millenium*. 2000, Transportation Research Board: Washington DC.
10. Mokhtarian, P.L., *A Typology of Relationships Between Telecommunications and Transportation*. Transportation Research A, 1990. **24**(3): p. 231-242.
11. Reichman, S., *Travel adjustments and life styles: a behavioral approach*, in *Behavioral Travel -Demand Models*, P.R. Stopher and A.H. Meyburg, Editors. 1976, Lexington Books: Lexington, MA. p. 143-152.
12. Pas, E., *Analytically Derived Classifications of Daily Travel-Activity Behavior: Description, Evaluation, and Interpretation*. Transportation Research Record, 1982. **879**: p. 9-15.
13. Pas, E., *The effect of selected sociodemographic characteristics on daily travel-activity behavior*. Environment and Planning A, 1984. **16**: p. 571-581.
14. Bhat, C. and F. Koppelman, *A Conceptual Framework of Individual Activity Program Generation*. Transportation Research, 1993. **27A**(6): p. 433-446.
15. Bowman, J.L., et al. *Demonstration of an Activity-Based Model System for Portland*. in *8th World Conference on Transport Research*. 1998. Antwerp, Belgium.
16. Ben-Akiva, M. and J.L. Bowman, *Integration of an Activity-based Model System and a Residential Location Model*. Urban Studies, 1998. **35**(7): p. 1131-1153.
17. Bhat, C.R., J.P. Carini, and R. Misra, *Modeling the Generation and Organization of Household Activity Stops*. Transportation Research Record, 1999. **1676**: p. 153-161.
18. Misra, R. and C.R. Bhat, *Activity Travel Patterns of Non-Workers in the San Francisco Bay Area: Exploratory Analysis*. Transportation Research Record, 2000. **1718**: p. 43-51.
19. Jonnalagadda, N., et al., *Development Of Microsimulation Activity-Based Model For San Francisco: Destination And Mode Choice Models*. Transportation Research Record, 2001. **1777**: p. 25-35.
20. Kitamura, R., *An Evaluation of Activity-based Travel Analysis*. Transportation, 1988. **15**: p. 9-34.
21. Bradley Research and Consulting, et al., *A System of Activity-Based Models for Portland*. 1998.

22. Gould, J. and T. Golob, F., *Shopping without travel or travel without shopping? An investigation of electronic home shopping*. *Transport Reviews*, 1997. **17**: p. 355-376.
23. Ma, J. and K.G. Goulias, *A dynamic analysis of person and household activity and travel patterns using data from the first two waves in the Puget Sound Transportation Panel*. *Transportation*, 1997. **24**(3): p. 309-331.
24. Bhat, C.R. and R. Misra, *Discretionary Activity Time Allocation of Individuals Between In-Home and Out-of-Home and Weekdays and Weekends*. *Transportation*, 1999. **26**: p. 193-209.
25. Salomon, I., *Telecommunications and Travel*. *Journal of Transport Economics and Policy*, 1985. **19**(3): p. 219-235.
26. Marker, J.T. and K. Goulias. *A Framework for the Analysis of Grocery Teleshopping*. in *79th Annual Transportation Research Board*. 1999.
27. Hjorthol, R.J., *The Relation Between Daily Travel and Use of the Home Computer*. *Transportation Research A*, 2002. **36**: p. 437-452.
28. Viswanathan, K. and K.G. Goulias, *Travel Behavior Implications of Information and Communications Technology in Puget Sound Region*. *Transportation Research Record*, 2001. **1752**: p. 157-165.
29. Pendyala, R.M., K.G. Goulias, and R. Kitamura, *Impact of Telecommuting on Spatial and Temporal Patterns of Household Travel*. *Transportation*, 1991. **18**: p. 383-409.
30. Wells, K., et al., *Telecommuting Implications for Travel Behavior: Case Studies from Minnesota*. *Transportation Research Record*, 2001. **1752**: p. 148-156.
31. Handy, S.L. and P.L. Mokhtarian, *Planning For Telecommuting*. *Journal of the American Planning Association*, 1995. **61**(1): p. 99-111.
32. Mokhtarian, P.L., *Defining Telecommuting*. *Transportation Research Record*, 1991. **1305**: p. 273-281.
33. Mokhtarian, P.L. and I. Salomon, *Modeling the Choice of Telecommuting: Setting the Context*. *Environment and Planning A*, 1994. **26**: p. 749-766.
34. Mokhtarian, P.L. and I. Salomon, *Modeling the Choice of Telecommuting: 2. A Case of the Preferred Impossible Alternative*. *Environment and Planning A*, 1996. **28**: p. 1859-1876.
35. Mokhtarian, P.L. and I. Salomon, *Modeling the Choice of Telecommuting: 3. Identifying the Choice Set and Estimating Binary Choice Models for Technology-based Alternatives*. *Environment and Planning A*, 1996. **28**: p. 1877-1894.
36. Mokhtarian, P.L., *A Synthetic Approach to Estimating the Impacts of Telecommuting on Travel*. *Urban Studies*, 1998. **35**(2): p. 215-241.
37. Handy, S. and P. Mokhtarian, *Forecasting Telecommuting: An Exploration of Methodologies and Research Needs*. *Transportation*, 1996. **23**: p. 163-190.
38. Lund, J.R. and P.L. Mokhtarian, *Telecommuting and Residential Location: Theory and Implications for Commute Travel in Monocentric Metropolis*. *Transportation Research Record*, 1994. **1463**: p. 10-14.
39. Nilles, J.M., *The Telecommunications-Transportation Tradeoff: Development of Policy*. 1976, New York City: Wiley. 196.
40. Niles, J., *Beyond Telecommuting: A New Paradigm For The Effect of Telecommunications on Travel*, . 1994, Department of Energy: Washington DC.
41. Golob, T.F. and A.C. Regan, *Impacts of Information Technology on Personal Travel and Commercial Vehicle Operations: research challenges and opportunities*. *Transportation Research C*, 2001. **9**: p. 87-121.
42. Yen, J.-R., H.S. Mahmassani, and R. Herman, *Employer Attitudes and Stated Preferences Toward Telecommuting: An Exploratory Analysis*. *Transportation Research Record*, 1994. **1463**: p. 15-.
43. Bernardino, A. and M. Ben-Akiva, *Modeling the Process of Adoption of Telecommuting: Comprehensive Framework*. *Transportation Research Record*, 1996. **1552**: p. 161-170.
44. Kitamura, R., et al., *Telecommuting as a Transportation Planning Measure: Initial Results of California Pilot Project*. *Transportation Research Record*, 1990. **1285**: p. 98-104.
45. Mokhtarian, P.L., *Telecommuting and Travel: State of the Practice, State of the Art*. *Transportation*, 1991. **18**: p. 319-342.
46. Mokhtarian, P.L., S.L. Handy, and I. Salomon, *Methodological Issues in the Estimation of Travel, Energy, and Air Quality Impacts of Telecommuting*. *Transportation Research A*, 1995. **29**(4): p. 283-302.
47. Kraut, R.E., *Telecommuting: The Trade-offs of Home Work*. *Journal of Communication*, 1989. **39**(3): p. 19-47.
48. Shen, Q., *Transportation, Telecommunications and the Changing Geography or Opportunity*. *Urban Geography*, 1999. **20**: p. 334-355.
49. Guiliano, G., *Information Technology, Work Patterns and Intra-metropolitan Location: A Case Study*. *Urban Studies*, 1998. **35**(7): p. 1077-1095.
50. Hamer, R., et al., *Teleworking in the Netherlands: An Evaluation of Changes in Travel Behaviour - Further Results*. *Transportation Research Record*, 1992. **1357**: p. 82-89.

51. Hamer, R., E. Kroes, and H.v. Oosterroom, *Teleworking in the Netherlands: An Evaluation of Changes in Travel Behaviour*. Transportation, 1991. **18**: p. 365-382.
52. Salomon, I., H.N. Schneider, and J. Schofer, *Is Telecommuting Cheaper Than Travel? An Examination of Interaction Costs in a Business Setting*. Transportation, 1991. **18**: p. 291-318.
53. Nilles, J.M., *Traffic Reduction by Telecommuting: A Status Review and Selected Bibliography*. Transportation Research, 1988. **22A**: p. 301-317.
54. Nilles, J., *City of Los Angeles Telecommuting Project Final Report*, . 1993, JALA International Inc.: Los Angeles. p. 89.
55. Mokhtarian, P.L. and R. Meenakshisundaram, *Beyond Tele-substitution: Disaggregate Longitudinal Structural Equations Modeling of Communication Impacts*. Transportation Research C, 1999. **7**(1): p. 330-352.
56. Salomon, I. and F. Koppelman, *A Framework For Studying Teleshopping Versus Store Shopping*. Transportation Research A, 1988. **22**: p. 247-255.
57. Salomon, I. and F.S. Koppelman, *Teleshopping or going shopping? An Information Acquisition Perspective*. Behaviour and Information Technology, 1992. **11**(4): p. 189-198.
58. Gould, J., *Driven to Shop? Role of Transportation in Future Home Shopping*. Transportation Research Record, 1998. **1617**: p. 149-156.
59. Couclelis, H., *Pizza over the Internet: E-commerce, the Fragmentation of Activity, and the Tyranny of the Region*. Entrepreneurship and Regional Development, forthcoming. **forthcoming**.
60. Mokhtarian, P.L., A. Nagurney, and J. Dong, *Teleshopping versus Shopping: A Multicriteria Network Equilibrium Framework*. Mathematical and Computer Modelling, 2001. **34**: p. 783-798.
61. Underhill, P., *Why We Buy: The Science of Shopping*. 1999, New York: Simon and Schuster. 255.
62. Batty, M., *The Retail Revolution*. Environment and Planning B, 1997. **29**: p. 1-2.
63. Handy, S. and T. Yantis, *The Impacts of Telecommunications Technologies on Nonwork Travel Behavior*, . 1997, Southwest Region University Transportation Center: Austin, TX. p. 51.
64. Cairns, S., *Delivering Alternatives: Successes and Failures of Home Delivery Services for Food Shopping*. Transport Policy, 1996. **3**(4): p. 155-176.
65. Kilpala, H.K., P.N. Seneviratne, and S.M. Pekkarinen. *Electronic Grocery Shopping and Its impact on Transportation and Logistics and Special Reference to Finland*. in *79th Annual Meeting of the Transportation Research Board*. 2000. Washington DC: Transportation Research Board.
66. Koppelman, F., I. Salomon, and K. Proussaloglou, *Teleshopping or Store Shopping? A Choice Model for Forecasting the Use of New Telecommunications-Based Services*. Environment and Planning B, 1991. **18**(4): p. 473-489.
67. Preece, J., *Sociability and Usability in Online Communities: Determining and Measuring Success*. Behaviour and Information Technology, 2001. **20**(5): p. 347-356.
68. Nilles, J.M., *Telecommuting and Urban Sprawl: Mitigator or Inciter?* Transportation, 1991. **18**: p. 411-432.
69. Bhatnagar, A., S. Misra, and H.R. Rao, *On Risk, Convenience, and Internet Shopping Behavior*. Communications of the ACM, 2000. **43**(11).
70. Cox, B., *E-commerce - Color it Green*, in *CyberAtlas*. 2002.
71. Talarzyk, W. and R. Widing, *Direct Marketing and Online Consumer Information Services: Implications and Challenges*. Journal of Direct Marketing, 1994. **8**(4): p. 6-17.
72. ePaynews, *Compiled Statistics*, . 2002, <http://www.epaynews.com/statistics/purchases.html#24>.
73. Pastore, M., *Wireless Voice Encroaching on Wireline Customers*, in *Cyber Atlas*. 2002.
74. Horrigan, J.B. and L. Rainie, *Getting Serious Online*, . 2002, Pew Internet and American Life Project: Washington D.C. p. 22.

Table 1. Mapping the literature of travel and ICT relating to three purposes of activity		
	Primarily Conceptual	Primarily Empirical
Subsistence	-Handy, 1995 [31] -Mokhtarian, 1990 [10] -Mokhtarian, 1991 [32] -Mokhtarian, 1994 [33] -Mokhtarian, 1996 [34] -Mokhtarian, 1996 [35] -Mokhtarian, 1998 [36] -Handy, 1996 [37] -Lund, 1994 [38] -Nilles, 1976 [39] -Niles, 1994 [40] -Golob, 2001 [41] -Golob, 2001 [7] -Yen, 1994 [42] -Salomon, 1986 [8] -Bernardino, 1996 [43]	-Kitamura, 1990 [44] -Pendyala, 1991 [29] -Wells, 2001 [30] -Mokhtarian, 1991 [45] -Mokhtarian et al, 1995 [46] -Mokhtarian, 1996 [34] -Mokhtarian, 1996 [35] -Kraut, 1989 [47] -Shen, 1999 [48] * -Guiliano, 1998 [49] -Hamer, 1992 [50] -Hamer, 1991 [51] -Salomon, 1991 [52] -Nilles, 1988 [53] -Nilles, 1993 [54] -Yen, 1994 [42] -Mokhtarian, 1999 [55]
Maintenance	-Salomon, 1988 [56] -Salomon, 1992 [57] -Gould, 1998 [58] -Gould, 1997 [22] -Marker, 1999 [26] -Coculelis, 2002 [59] -Mokhtarian, 2001 [60] -Golob, 2001 [41] -Golob, 2001 [7] -Underhill, 1999 [61] -Batty, 1997 [62]	-Handy, 1997 [63] -Kraut, 1989 [47] -Cairns, 1996 [64] -Kilpala, 2000 [65] -Koppelman et al, 1991 [66]
Discretionary	-Salomon, 1988 [56] -Salomon, 1985 [25] -Salomon, 1992 [57] -Underhill, 1999 [61]	-Handy, 1997 [63] -Hjorthol, 2002 [27] -Kraut, 1989 [47] -Preece, 2001 [67] -Koppelman et al, 1991 [66]
Notes: -Some papers describe both theoretical and empirical aspects and are listed in each column. -Some papers relate to more than one category and may be listed in multiple rows. * This research focuses less on the impact of direct work travel and more on the impact that telecommuting has on accessibility indices. It is grouped under subsistence because of the primary focus on employment opportunities.		

Figure 1. Dimensions for further research of ICT and household travel

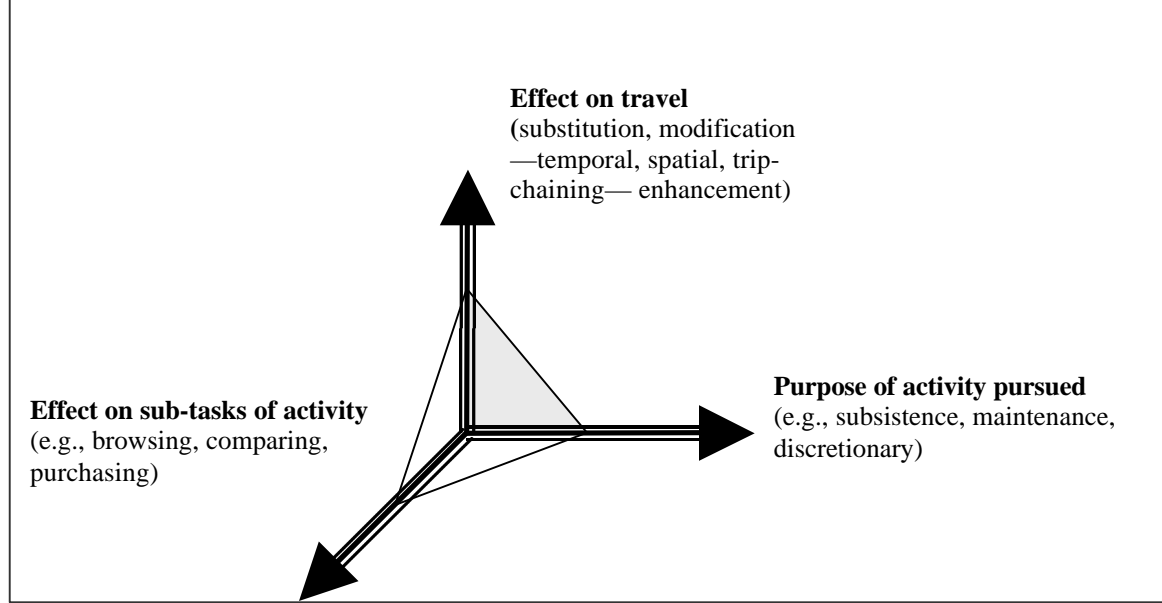


Figure 2. Examples of the complexity in which ICT affects travel

