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Impacts of Information Technology on Personal Travel and Commercial Vehicle Operations: Research Challenges and Opportunities

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Abstract

Travel, like many other aspects of daily life is being transformed by the information technology revolution. Accessibility can no longer be measured only in terms of travel time, distance or generalized travel cost. Information technology gives people virtual accessibility to a rapidly growing range of activities. E-commerce has become a catalyst for structural changes in the freight transportation industry and is changing where freight moves, the size of typical shipments and the time within which goods must be delivered. In this paper we explore some of the potential effects of information technology on transportation, both personal and freight.

Keywords: Travel demand forecasting, Information technology, Telecommunications, Internet, Telematics, E-commerce, Activity analysis, Freight transportation, Commercial vehicle operations

1. OBJECTIVES AND SCOPE

In this paper we explore some of the potential effects of information technology (IT)¹ on transportation, both personal and freight. The Internet and the proliferation of capable and affordable computers and communication devices have made electronic commerce (e-commerce) the fastest growing sector of most western economies. For many people, the home has become a viable site for the conduct of certain activities that formerly could only be conducted at non-home locations. In addition, cellular telephones and other portable computer and communications devices have redefined our ability to conduct business and dynamically schedule activities while traveling or at locations away from home or workplace. IT also encourages flexible working arrangements, such as telecommuting.

Freight transportation is being affected by IT developments in many different ways. Individual modes are made more effective by the use of communication technologies coupled with specialized routing and scheduling, vehicle monitoring and maintenance and record keeping software. Web-based load matching systems, both free and fee based, aid carriers in finding loads. On-line auctions match freight and automate the bidding process. Intermodal freight transportation, particularly maritime and air cargo is being transformed by IT. Tracking and tracing technologies for containers and packages are gaining widespread use, and web based information clearing houses are providing key information to improve the efficiency of modal transfers. The freight forwarder and customs brokerage industries are being transformed by new industry entrants and existing companies rushing to provide a wider array of information rich services.

The wave of technological advances that brought us the Internet, mobile phones, and personal digital assistants is not likely to slow down. The future will bring a next-generation Internet with higher speed, multimedia capability and intelligent agent technology. It will be accessible by both PC's and "Internet appliances" such as television set-top boxes, videogame consoles and smart handheld devices.

Accessibility can no longer be measured only in terms of travel time, distance or generalized travel cost. Information technology gives people virtual accessibility to a rapidly growing range of activities. Each person who shops at home on the Internet, or uses a handheld Internet device to gather information about the transportation system before embarking on a trip, might only change his or her overall pattern of travel behavior just a little. But there are millions of people worldwide who will be doing similar things on any one day. The small effects scale up to be significant. Travel behavior researchers need to develop models that are capable of capturing the present and future impacts of telecommunications on travel.

The changes in goods movement may be dramatic as well. Average shipment sizes, sensitive to changing inventory practices may go down, leading to an increase in the

¹Information technology (IT) is also variously referred to as information and communications technology (or information and computer technology) (ICT) or new information technology (NIT).

number of truck trips and a reduction in average vehicle sizes. However, increased opportunity for consolidation of shipments, made possible by web-based load matching systems and services may balance out this trend, at least for long distance moves.

Sections of this paper are adapted from Golob (2000a). The discussion in Golob (2000a) is confined to personal travel behavior and is centered around the application of activity analyses. Here, we take a more general view of the impacts of IT on both personal travel and commercial vehicle operations.

The remainder of this paper is organized into seven major sections. We briefly review studies related to the impact of IT on travel in the next section, along with studies of technology adoption in commercial vehicle operations. This is followed by a review of relevant information technologies. The next two major sections address potential impacts on personal travel behavior and commercial vehicle operations as well as reviewing some of the most relevant literature. We close with a discussion of data needs, policy implications of studies of IT and then present some brief conclusions.

2. PREVIOUS STUDIES

The transportation research community is becoming increasingly sensitive to impacts of IT on travel. On the personal travel side, Hensher and J. Golob (1997), Mokhtarian and Salomon (1997), and Mokhtarian (2000) examine research issues in the study of telecommunications and travel patterns. These overviews have generally limited telecommunications to point-to-point interactive communications networks. Predating these studies, and the Internet itself, is a series of earlier works that addressed questions that are still valid today (Koppelman, *et al.*, 1991, Salomon, 1985, 1986, 1990 Salomon and Koppelman, 1988, 1992, Salomon, *et al.*, 1991 Salomon and Schofer, 1988). Unfortunately, many of the conclusions of these and other earlier studies are outdated, because the capabilities of new IT was unforeseen just a few years ago. Specific studies that focus on aspects of travel or activity behavior impacted by IT are reviewed in Section 4.

On the freight side, there is increasing interest in modeling shipper and carrier technology adoption. Given the rapid pace of technological development, the empirical results of studies of the adoption of technology become obsolete rapidly. Among these earlier studies, Scapinakis and Garrison (1991) conducted a small survey regarding carriers' perceptions of use of communications and positioning systems, and Kavalaris and Sinha (1994) surveyed trucking companies with a focus on their awareness of and attitudes towards ITS technologies. Ng *et al.* (1996) reported results from two nationwide surveys of dispatchers and commercial vehicle operators to determine characteristics that would determine likely acceptance of Advanced Traveler Information Systems (ATIS) technologies, including route guidance, navigation, road and traffic information, roadside services and personal communication. Regan, *et al.* (1995) surveyed 300 companies to determine carriers' propensity to use new technologies,

particularly two-way communication and automatic vehicle location/identification technologies. Holguin-Veras and Walton (1996) also investigated the use of IT in port operations through interviews with port operators and a small survey of carriers. Crum et al. (1998) studied the use of electronic data interchange (EDI) technology, and Hall and Intihar (1997) studied IT adaptation through a series of interviews with trucking terminal managers, focus group meetings with representatives of the trucking industry, and telephone interviews with technology providers. Most recently, Golob and Regan (2000b), present a multivariate discrete model of trucking industry adoption of communication and information technologies based on a survey of nearly 1200 US carriers.

3. RELEVANT INFORMATION TECHNOLOGY

Technological developments that are likely to influence personal travel and activity behavior are reviewed in Golob (2000a). Here, we reorganize and expand this review to include technologies that affect commercial vehicle operations as well.

3.1. Computer Technology

Technological advances in microchips continue to make personal computers more capable, affordable, and compact, as predicted in part by Moore's Law². Many people use computers at home and portable computers for both work and household activities. The popularity of personal computers is due in large part to the Internet, which is discussed in the next section. The Internet provides connectivity to the outside world – virtual accessibility. The advances that made personal computing attractive in business – appropriate applications software, efficient and intuitive user interfaces, and local area networks – were not sufficient alone to make personal computing attractive for non-work applications in households. Telecommunication capability and access to information was also needed. By 1999, computers were in about 44 percent of U.S. households.

The vast market for the hardware and software technology by which home computers can be connected to the Internet is ensuring that technological developments keep pace with demand. In the late 1990s, dial-up modem speeds increased and costs decreased until the limitations of twisted-wire telephone connections were reached. This has been followed by television cable modems and DSL (digital subscriber lines). The number of broadband Internet connections to homes in the U.S. is forecast to increase by 250% from 1999 to 2000 (IDC, 1999). In 1999 there were approximately 1,500,000 cable modems in operation, and the number is forecast to reach 45 million by 2007 (Pioneer Consulting, 1999). The future is also likely to include set-top boxes, which enable television sets to become interfaces to the Internet. These devices, which are essentially specialized computers loaded with TCP/IP and web HTTP clients (Web

² In 1965, Gordon Moore, a founder of Intel Corporation, predicted that the processing power of microchips would continue to double every eighteen months. So far, this has approximately held true.

browsers), might be attractive to new segments of the population who have not become familiar with traditional computers through work or educational experiences. Videogame consoles are now also going online and will likely provide future set-top Internet access that goes beyond online multi-player gaming. Videogame manufacturers are all linking up with Internet providers to develop online devices, some of which come with built-in modems (Industry Standard, 1999). IT industry consultants (e.g., Gens, 1998) predict a transition from home computers to “information appliances”.

The next technologies in the sequence appear to be very small portable computers with wireless communication and satellite-based Internet distribution services (Minei and Cohen, 1999, Pioneer Consulting, 1999). Wireless devices are discussed in Section 3.3. Direct satellite links, marketed up until now almost exclusively for television broadcasts, will expand high-speed connectivity to areas poorly served by other technologies. The ultimate advantages of satellite Internet connections, which will probably be combined with television reception, are faster access time, lower cost, distance insensitivity, and bypass of terrestrial network bottlenecks and problems.

3.2. The Internet

The genesis of the Internet can be traced to developments in packet switching technology in the 1960's. The first packet-switched network, ARPANET, funded by the Advanced Research Projects Agency of the U.S. Department of Defense, is considered the direct ancestor of the Internet. The evolution of ARPANET and its successors into the Internet as we know it today is traced by Golob (2000), Kurose and Ross (2000), Leiner, *et al.* (1998), and Zakon (2000). Important early steps in this development include the inventions of email, the Transmission Control Program (later TCP/IP), the Ethernet protocol for local area networks (LAN's). In 1991, The World Wide Web (WWW) was released by CERN, the European Laboratory for Particle Physics. The WWW pioneered the use of HTML (hypertext markup language), HTTP (hypertext transfer protocol), Web servers, and Web browsers. By 1992, the number of network hosts reached 1 million. GUI (graphical user interface) Web browsers came into being in 1993 and 1994 with the release of Mosaic (which became the foundation for Netscape). In 1995 dial-up Internet connections began to be provided in the U.S. by for-profit companies (e.g., CompuServe, America Online, Prodigy). There were estimated to be approximately 5,800,000 Internet hosts in January 1995. This number grew to about 56 million by July 1999, as graphed in Figure 1 (data from Zakon, 2000).

In 1999, the Internet grew by 60,000 Web pages a day, and at the end of the year there were more than 5 million registered domain names. The number of Web pages is forecast to grow to 7.7 billion by 2002 (IDC, 1999). Estimates vary, depending on what is being measured and how it is being measured, but it is generally agreed that, at the present time, Internet traffic currently doubles every eight months or so. During the one-year period from May 1999 to May 2000, the number of worldwide Internet hosts increased 44%, from 55.72 million to 79.99 million (Telcordia, 2000).

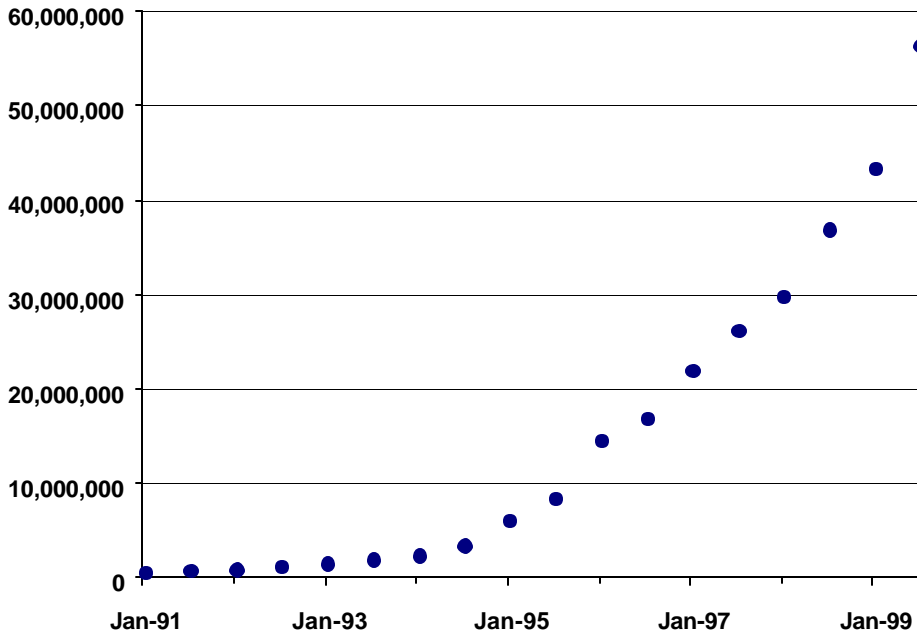


Figure 1. Growth in Internet Hosts, 1995 to 1999.

The number of worldwide Internet users (adults over sixteen engaged in weekly Internet access from home or business) was estimated at about 182 million at the end of 1998 and stands at well over 200 million today (IDC, 1999). Forecasts of growth vary, but one source (Computer Industry Almanac, 2000), predicts 766 million worldwide by 2005, more than a four-fold increase in five years. Another source (IDC, 1999) predicts a billion-user Internet in 2005. In 1998, almost half of all adult Internet users resided in North America. But, as shown in Figure 2, this is expected to change as other parts of the world become connected. By 2005, both Western Europe and the Asia-Pacific region are each expected to have almost as many Internet users as North America (Computer Industry Almanac, 2000). The total numbers of Internet users in the rest of the world will be considerably less than in these first three regions, but the proportional increases in the number of users in the Middle east and Africa, South and Central America, and Eastern Europe could be phenomenal. At the present time, it is estimated that the average Internet user in the U.S. spends 12.1 hours per week online (Intelliquest, 2000).

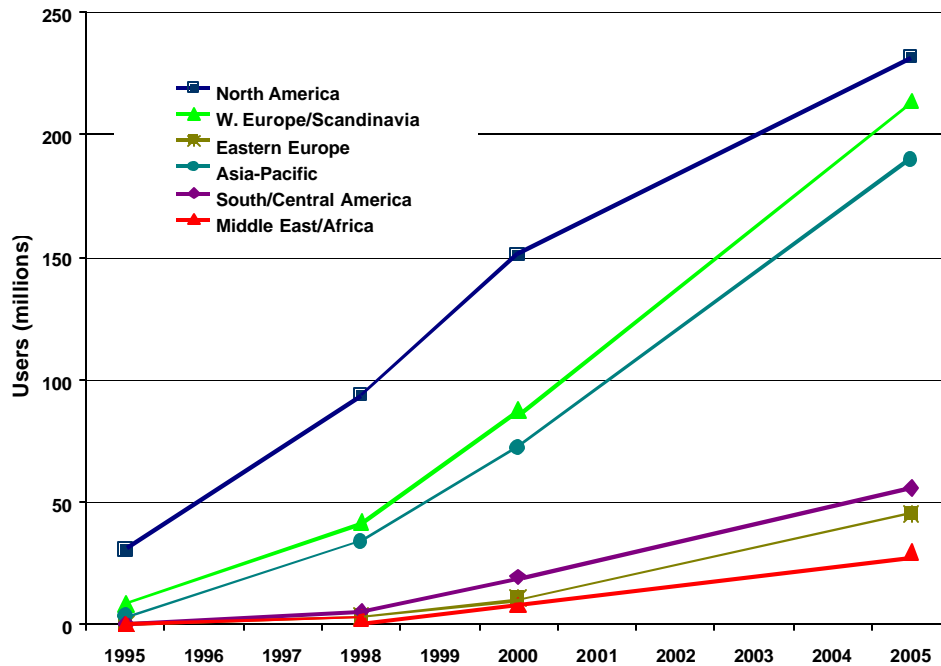


Figure 2. Growth in Adult Internet Users by Region, 1995 to 2005.

Corresponding estimates of the number of Internet users per capita by region are shown in Figure 3 (based on data from Computer Industry Almanac, 2000). In North America, it is forecast that seven out of every ten adults over sixteen will be regular Internet users by 2005, while in Western Europe and Scandinavia this ratio is likely to be five out of ten. Currently, the highest Internet use per capita is in the Scandinavian countries of Iceland, Finland, Norway and Sweden, but the ratio for the entire region is brought down by lower usage per capita in Southern European countries. Per capita Internet use in France is depressed because of the previous heavy commitment to the separate Videotex Télétel (Minitel) system, but France Télécom has launched a project to provide Internet access via Minitel without use of a PC (OECD, 1998). Per capita Internet use will likely remain much lower in Asia, being projected at only about 50 per 1,000 population in 2005. But the large regional population base will ensure that the total number of Internet users in Asia will eventually rival North America and Europe.

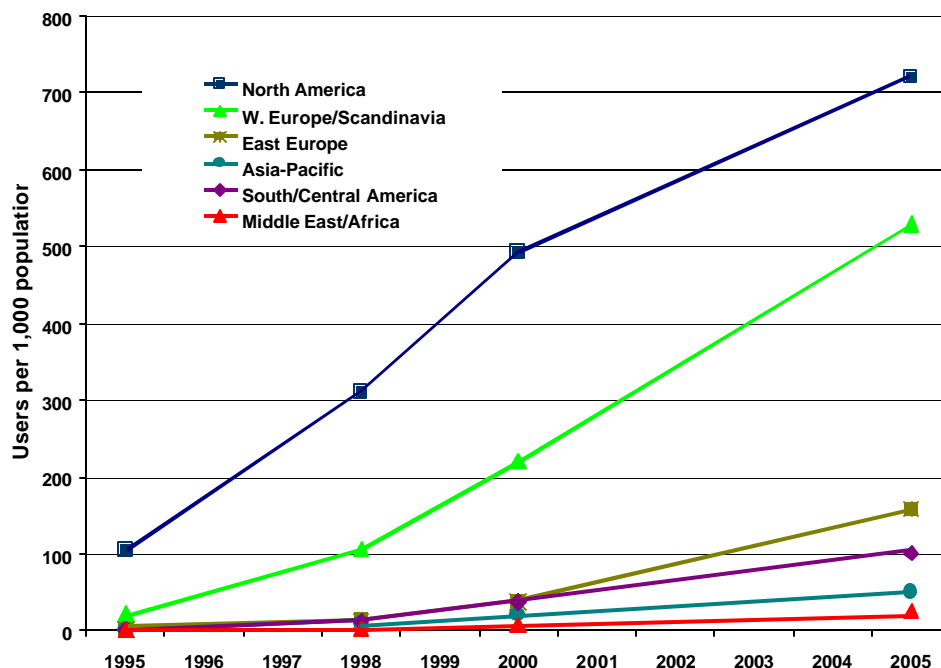


Figure 3. Growth in Adult Internet Users per Capita by Region, 1995 to 2005.

Internet connectivity introduces potential equity issues in the information age. In the U.S., it is estimated that 41% of the population has access to the Internet either at home or at work, and an additional 9% of the population have access through schools and libraries (Arbitron, 2000). To the extent that individuals are able to improve the quality of their lives by adjusting their activity and travel by using the Internet and related IT, these advantages will be distributed unequally across different groups in the population of most countries Golob (2000a). In the U.S., Internet access is a function of economic status, geographic location, age, race, ethnicity, and gender (Castells, 1989, 1996, Ebo, 1998).

The total Internet economy is large and rapidly growing. Table 1 lists the worldwide estimates of revenues generated from Internet-based business by U.S. firms (Barua *et al.*, 1999). The total world Internet economy is forecast to reach US\$ 2.3 trillion by 2003 (IDC, 1999). More than half of all revenue is generated by the Internet industry serving itself. However, a substantial portion of the Internet economy in the U.S. is in e-commerce, and this proportion is increasing over time. For purposes of investigating impacts on activity and travel behavior, the e-commerce economy must be broken into two components: consumer (business-to-consumer or residential) e-commerce, and business-to-business e-commerce. The European Internet economy is estimated to be about one-third of the U.S. Internet economy (IDC, 1999).

Table 1: The Internet Economy - Worldwide Estimates of Revenue for US-based Companies (Revenues in US\$ billions).

Layer of the Internet Economy	1st Quarter 1998	1st Quarter 1999	Growth 1998-1999
1. Infrastructure: Backbone providers, ISP, networking hardware and software, PC and server manufacturers, security vendors, fiber optics and line accelerator manufacturers	26.8	40.1	50%
2. Applications: Consultants, commerce and multimedia applications, web development and search engine software, online training and web-enabled databases	13.9	22.5	61%
3. Intermediary: Vertical-industry market makers, online travel agents and brokerages, content aggregators, portal and content providers, ad brokers, online advertising	11.0	16.7	52%
4. E-commerce: E-merchants, manufacturers selling online, fee/subscription-based companies, airlines selling online tickets, online entertainment/professional services	16.5	37.5	127%
Total quarterly revenues (after removing overlaps)	64.0	108.0	68%
Annual revenues (after removing overlaps; projected for 1999)	301.4	507.0	68%

The next generation Internet Protocol, IPv6 (previously known as IPng) is imminent. IPv6 is designed to relieve problems of address space exhaustion and router table explosion by allowing for growth up to 100 computers per human being, or 10^{15} computers connected by 10^{12} networks (Hinden, 1999). Next generation IP-based (multimedia) networks are being constructed around high speed (2.5 gigabytes or higher per second) backbones (Dècina and Trecordi, 1999).

Voice over Internet Protocol (VoIP) is also touted as leading to a pivotal reshaping of the communications industry. VoIP will finally bring full multimedia capability to the Internet (Dècina and Trecordi, 1999). It also enables phone calls to travel over the Internet as digital packets. VoIP is now a US\$ 290 million business, up from US\$ 130 million last year and is forecast to become a \$1.8 billion business by 2003 (IDC, 1999). It is difficult to predict what other technologies involving combinations of computers and communication devices lie ahead. There is a great deal of research underway in the field of multimedia communications.

The Other IT development that might prove to be particularly important for e-commerce, and hence travel behavior, involves the language of the Internet. Presently, most

information is transferred using hypertext markup language (HTML) understandable only through human eyes. Some information is also transferred among programs using languages such as CORBA (Common Object Request Broker Architecture), which cannot be read by humans. However, developments are proceeding on a language for the Internet called extensible markup language, or XML. XML is designed to be readily interpretable by both machines and humans. XML encodes information with meaningful structure and semantics that computers can readily understand, while retaining HTML-like properties. XML will provide a framework for intelligent agents and other robotics that will define the second-generation Internet, particularly e-commerce.

Agents (variously called autonomous, automated, intelligent, mobile, or software agents, or software robots or “bots”) are programs that act independently on behalf of their users in furtherance of their users’ interests. This is expected to revolutionize the Internet (Maes, *et al.*, 1999, Glushko, *et al.*, 1999, Wong, *et al.*, 1999). Agent technology is capable of doing for the Internet what graphical interfaces such as Windows and Macintosh did for the PC: provide an effective and friendly user interface (Vulkan, 1999). Agent-based technology is projected to become a US\$ 4 billion software market by the end of 2000 (Ovum, 2000). The anticipated impacts of agents on e-commerce are explored briefly in Sections 3.2.1 (consumer e-commerce) and 3.2.2 (business-to-business e-commerce).

3.3. Mobile Phones and Handheld Internet Devices

Mobile (portable wireless or cellular) phones are becoming omnipresent. Worldwide, at the beginning of 2000, the number of cellular subscriptions was 470 million, and this is forecast to grow to 1 billion by the end of 2003 (Ovum, 2000). Europeans lead the world in mobile phone use, with over 117 million subscriptions (Forrester, 2000). The market penetration of mobile phones in the U.S. has lagged behind many other countries (with only 69 million portable phones in the U.S. in 1999), but penetration is nevertheless expected to accelerate and reach 54% of the American population by 2004. Over the past few years, mobile phone technology has evolved from analog to digital voice communication, and a worldwide standard for third-generation digital (3G Wireless) will come online in 2000 through 2002 (CTIA, 2000). One billion mobile phone subscribers are forecast worldwide by 2005, but a substantial portion of these phones will have multimedia capabilities (Nokia, 2000). If there are a billion mobile phones worldwide by 2005, this will be more than all PC’s and automobiles combined.

Multimedia capability ensues when mobile communication shifts from voice-only to a combination of voice and data. Mobile phones and pagers with short messaging services (SMS) are now in common use (with an 11% penetration in Europe). But the major new development is in mobile phones and other held-held devices enabled with Internet access. These devices, generally referred to as smart phones, Webphones, or wireless intelligent terminals, are made possible by the fledgling “Microbrowser” Wireless Applications Protocol (WAP) and third-generation CDMA (code division multiple access) transmission interface technology. In 1999, France Télécom began

testing the use of smart phone technology to allow users of its Videtex Télétel system to access the Internet.

It is forecast that the number of Internet-enabled mobile phones using WAP and its successors will soar from 1.1 million at the end of 1999 to anywhere from 21 to 80 million worldwide in 2003 (Dataquest, 2000, In-Stat, 2000, Yankee Group, 2000 and Jupiter Communications, 2000). Even by the end of 2001, it is estimated that 28 million Americans will be using mobile phones for data transfer, 75% of these using SMS and 25% using smart technology (IDC, 1999). One source (Dataquest, 2000) predicts that shipments of internet-enabled wireless devices will outstrip PC's by 2003.

Improvements in transmission capability required by WAP devices will be supplied by huge infrastructure investments (including many more satellites) and the massive introduction of Bluetooth technology. Bluetooth, named after a fierce 8th century Viking (Harald Blåtand), is an advanced radio technology that is designed to operate in noisy, uncoordinated radio frequency environments, utilizing extremely fast acknowledgement and frequency-hopping schemes and forward error correction. It is anticipated that more than 75% of all handsets shipped in 2004 will be Bluetooth-enabled (Dataquest, 2000). This technology will help transform the mobile phone into a true multi-purpose wireless communication device.

3.4. Private Commercial Communications Systems

In addition to advances in cellular telephony, commercial vehicle operators have access to a myriad of communications technologies. Satellite based communication and positioning systems are used to provide real-time communication, location, status updates and to monitor vehicle conditions (temperature for example) remotely. Hand held or home office wireless communication devices can be used to track and trace packages and shipments from any location.

The geosynchronous satellite communication and location system developed by Qualcomm in the late 1980's is still popular among large long distance carriers. That system and similar ones are increasingly facing stiff competition from competing wireless communication systems which use a wide variety of local communication options. These systems, most of which rely on handheld wireless devices rather than on "traditional" on-board computer systems are gaining popularity because of their flexibility and relative low cost in urban operations.

Communication systems for commercial vehicle operations automate a variety of processes. As discussed by Klingenberg(1998), these include safety assurance (real-time safety information exchange, automated safety inspection and on-board safety monitoring), credentials administration (electronic application and issuance of credential), electronic screening (automated weight and credentials screening) and carrier operations (fleet and vehicle management, route information and hazardous-materials incident response).

3.5. Software

Specialized software packages have been developed for many different aspects of freight logistics operations. These are not limited to: inventory management, equipment distribution and dispatch, fleet location and status monitoring, routing and scheduling optimization, container management, marginal and average cost modeling, air cargo reservation systems and freight rating.

4. POTENTIAL IMPACTS ON PERSONAL TRAVEL BEHAVIOR

Information technology is affecting personal travel in a myriad of ways, as described in more detail in Golob (2000a). The discussion that follows organizes these into eight categories: (1) online shopping (consumer e-commerce), (2) other online services, especially telemedicine, (3) flexible working arrangements, including telecommuting (or teleworking), (4) self-employment, (5) contingent and part-time working arrangements, (6) mobile working, and (7) education.

4.1. Consumer Electronic Commerce

Estimates of e-commerce as a proportion of present business vary greatly, depending upon how e-commerce is defined. However it is defined, most e-commerce occurs between businesses. Probably about 20% of all e-commerce in the U.S. in 1999 can be classified as consumer (business-to-consumer or residential); the rest is e-commerce between companies (business-to-business). Growth curves for *worldwide* e-commerce, separated into consumer and business-to-business, are shown in Figure 4 (based on data from IDC, 1999). Figure 4 shows US\$ 1.3 trillion in e-commerce revenues by 2003. While this estimate has been extensively cited (e.g., Financial Times, 1999), other forecasts are more optimistic. Another industry observer (Boston Consulting Group, 2000) predicts that one-fourth of all U.S. business-to-business purchases will be online by 2003, and at the time business-to-business e-commerce will reach US\$ 2.8 trillion in transaction value.

The recent growth in consumer e-commerce on the Internet has been phenomenal. Limited e-commerce services have been available since the 1980's for users of Videotex systems, such as Télétel. In 1980 the French government launched Télétel, a Videotex telephone-based packet-switched network originally designed to provide an online telephone directory. In 1984 the French government began distributing free Minitel terminals with low-speed modems to any French household that applied for one. By 1995, Minitel offered more than 20,00 different free and user-fee services, ranging from directories to banking and reservation systems, and it was used by over 20% of the French population (Kurose and Ross, 2000). Télétel spawned similar Videotex

systems in other countries (e.g., Prestel in the U.K.) and is still in widespread use in France.

In 1999, it is estimated that 7 million households in the U.S. made their very first online purchases. It is also estimated that more than 17 million U.S. households shopped online by the end of 1999, and the forecast is that 49 million U.S. households will shop online by 2004 (Forrester, 2000). At the present time, in early 2000, 10% of U.S. households shop online (Ernst and Young, 1999).

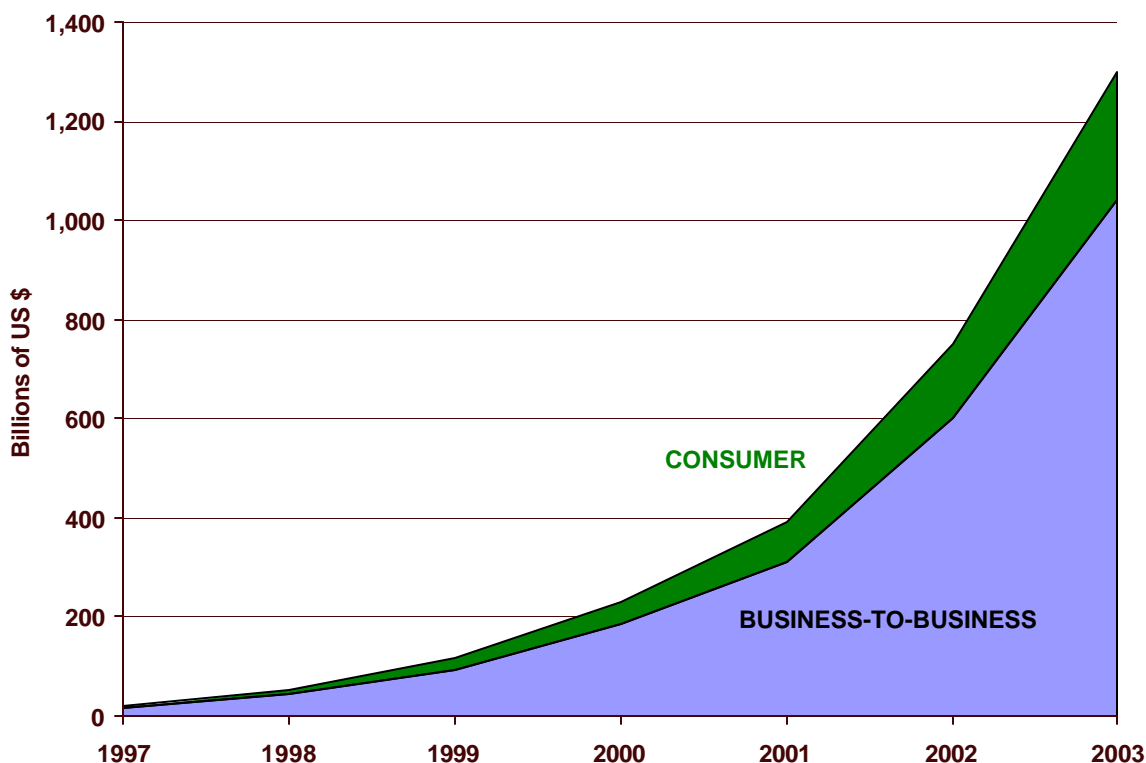


Figure 4: Growth in Worldwide E-commerce Revenues.

Revenues from consumer e-commerce in the U.S. for 1999 are estimated to be anywhere from US\$ 20 billion (IDC, 1999) to US\$ 36 billion (Boston Consulting Group, 2000), up from US\$ 4 billion in 1997 and US\$ 10 billion in 1998. A conservative projection is for US\$ 54 billion in 2002, representing a compound annual growth rate of almost 60% (IDC, 1999). Another estimate has U.S. consumer e-commerce at US\$ 184 billion by 2004 (Boston Consulting Group, 2000). The rest of the world is lagging behind the U.S., but regions such as Europe are rapidly catching up. Forecasts vary partly because a major component of growth in is in terms of first-time buyers, and it is not well understood how the repeat buyer will behave over longer periods of time. Also,

early adopters still make up a substantial portion of the all e-commerce, and it is not well understood how later adopters will conduct their business.

The major reasons for the expectations of accelerating growth in consumer e-commerce are the imminent advances in information technology discussed in Section 3. In large part, these technologies are being driven by aspirations to make e-commerce more attractive and effective. Some of these new technologies include connections to a higher-speed multimedia Internet through television set-top boxes and handheld Internet devices. Perhaps most importantly, the next-generation Internet will incorporate VoIP (voice over Internet Protocol), XML (extensible markup language) and intelligent agents (software “bots”). These advances will allow e-consumers to send out intelligent agents to find best values and new opportunities (Vukan, 1999; Maes, *et al.*, 1999; Glushko, *et al.*, 1999). The advances will also allow personalized human-assisted e-commerce (Dècina and Trecordi, 1999). Future e-commerce Websites might also employ virtual reality effects to make shopping a more realistic and exciting experience (Batty, 1996, 1997a, 1997b). Made more attractive and easy, consumer e-commerce might well become an integral part of daily activity patterns for millions of people worldwide. Travel behavior researchers need to recognize this, and we need to take immediate steps to begin to understand its consequences.

Currently, the major sectors of consumer e-commerce are books, software, music, travel (e.g., airline tickets), hardware, clothing, and electronics (Cyber Dialogue, 2000). As with all retail commerce in the U.S., online retail sales (including travel) peaks at the Christmas holiday period. In the near future, smaller e-merchants are expected to band together to form virtual malls, with portals to varieties of e-merchants, for “one-stop” Internet shopping.

There is also developing e-commerce in groceries and household goods. Industry observers disagree on the immediate potential for this sector, with estimates of revenues for 2000 in the U.S. varying from around US\$ 1-2 billion (Jupiter Communications, 2000) to US\$ 6 billion (Yankee Group, 2000). Even if online grocery shopping grows to about US\$ 11 billion by 2003, this will still only be 2% of the total grocery market (Forrester, 2000). Restricted geographic location, high development and maintenance costs of online inventory display, and high delivery costs are often cited as factors impeding the growth of grocery e-commerce. E-merchants in this sector are attempting to establish one of two types of markets: household replenishment or specialty luxury items (Forrester, 2000). Online shopping for groceries and household goods can be particularly important for activity and travel behavior, because this activity is much more repetitive than other types of shopping.

It is difficult to estimate how much of online consumer sales would have occurred at “bricks-and-mortar” businesses. One e-commerce industry source (Jupiter Communications, 2000) estimates that most online sales are shifted “from bricks to clicks,” and only a minority of online sales are shifted from over-the-phone catalog sales; thus only 6% of online sales would not have occurred otherwise. Many online shoppers also use the Internet as a research tool, to compare prices and features.

Another industry observer (Cyber Dialogue, 2000) estimates that Internet shopping influenced US\$ 51 billion in offline spending in 1998. Also in 1998, it is estimated that more than five million new car buyers and 26% of used car buyers in the U.S. compared features and prices on the Internet (J.D. Power, 1999).

Few e-commerce observers seriously believe that online shopping will replace a large proportion of shopping sojourns at bricks-and-mortar businesses in the foreseeable future. Shopping is often linked together with other activities, and there are many other reasons for shopping besides the ultimate purchase of a bundle of goods (Gould, 1998, Koppelman, *et al.*, 1991). Shopping also involves recreation, social contact, search for new opportunities and enjoyment of being outside, or being in an urban or village center environment.

On the other hand, this substantial shift of consumer purchases from brick-and-mortar businesses to e-commerce (from “bricks” to “clicks”) has to have some pronounced effect on travel and activity behavior, and that effect will surely increase over time. In 1995, it was estimated that shopping trips comprised one out of every five person trips and one out of every seven person miles traveled in the U.S. (NPTS, 2000). If, for each online shopper, only a few sojourns per year at bricks-and-mortar merchants are now replaced by e-commerce, the number of trips affected worldwide is relatively large. As online shopping becomes more accessible and attractive due to imminent advances in IT, and as Internet users become comfortable with online shopping, the individual impacts on activity and travel behavior will probably increase, while at the same time the number of online shoppers is increasing exponentially. Within a couple of years, the effect overall effect could well be huge.

Because trips for household replenishment make up a large portion of all shopping trips, much of the travel behavior research has concentrated on online grocery shopping (Gould, 1998, Gould and Golob, 1999, Kilpala, *et al.*, 2000, Marker and Goulias, 2000). Also, most of other consumer e-commerce in the U.S. is concentrated in the short holiday shopping season, and transportation planners have never been very concerned about seasonal congestion. After many failures (Cairns, 1996), on-line markets for specialty (gourmet, organic and ethnic) foods are showing promise, and a target market is likely to be fully employed female heads of households, who typically have very busy activity schedules. Gould and Golob (1997)(1999) forecast that some of the travel time saved by working women eliminating some shopping trips will be converted to travel for other purposes, but most of the saved time will be converted to activities at home. Of course, freight travel is also generated through the home delivery of online purchases.

With projections of 50 million households in the U.S., and possibly an equal or greater number in the rest of the world, shopping online by 2004, even relatively minor impacts on activity and travel patterns will aggregate substantially. As travel behavior researchers, we need to begin understanding how time spent in conducting shopping and personal business online compares to the traditional alternatives. We need to determine, for different segments of the population, which activities are

telecommunication substitutes and which are complements, with the objective of quantifying impacts on travel times and distances (Mokhtarian, 2000). In addition, we need to quantify the demand for freight transportation involved in home deliveries.

4.2. Other Teleservices

In addition to shopping, people will increasingly use the Internet for services such as banking, dealing with governmental agencies (for example, to gather information, register for services, pay taxes, or obtain permits), making travel arrangements, and many other personal business activities. In particular, telemedicine (online medical services) is becoming a very important part of medical practice (Bashshur, *et al.*, 1997, Viegas and Dunn, 1998). In the U.S., it is forecast that 33.5 million adults will use the Internet to find health and medical information in 2000, searching among the over 15,000 Internet healthcare sites (Cyber Dialogue, 2000). Development in telemedicine will probably have only infrequent effects on the activity patterns of most people, but these developments are likely to have profound effects on the activity patterns and transportation needs of some elderly and chronically ill people.

4.3. Flexible Working Arrangements

IT in the form of home computing, the Internet, fax machines and express mail delivery has increased the effectiveness of flexible working arrangements between employers and their employees. There are many quality-of-life advantages of sometimes or always working at home, as described by Shamir and Salomon (1985) and Christensen (1988). Advantages related to activity behavior include enhanced day-to-day flexibility in activity scheduling and the sharing of activities with household members, more opportunities for quality time with family members, and saved commuting travel time.

Telecommuting (or telework) generally refers to formal arrangements between employees and their employers regarding work conducted at home or at a remote center that is more convenient to the employee than his or her main workplace. (Telecommuting can also refer to informal arrangements, but there has been less research on this.) The effects of telecommuting on travel behavior have been extensively studied, largely through the efforts of Mokhtarian and Salomon and their colleagues. Recent reviews of telecommuting studies are provided by Handy and Mokhtarian (1996), Mokhtarian (1997)(1998), and Mokhtarian and Salomon (1997). A key issue is the degree to which telecommunications and travel are substitutes or complements in telecommuting behavior (Mokhtarian, 1990 and Niles, 1994). Part of saved commuting travel time and cost can be converted into new or longer trips for non-commuting purposes, and trips may be required in support of telecommuting activity itself or to replace trip purposes previously linked to commuting (induced demand). These effects are likely to be manifested over the long run and on days other than telecommuting days. Telecommuting opportunities might also influence residential and employment location choices, which in turn affect travel demand (Nilles, 1991,

Pendyala, *et al.*, 1991). Mokhtarian and Salomon (1996)(1997) and Salomon (1996) report that most studies have found that the effect of telecommuting on non-commuting trips is statistically insignificant. Additionally, no significant impact on mode choice or residential location has yet been measured.

Telecommuting is appealing to planners and politicians because it implies a reduction in commuting travel at no cost in terms of infrastructure and transportation services. The potential role of new IT in facilitating telecommuting also implies a technological solution to the congestion problem, appeal of which is undoubtedly responsible for generating overly-optimistic early forecasts of telecommuting adoption (Salomon, 1996). Induced demand is also an issue (Goodwin, 1996; Heanue, 1998).

The basic travel behavior question concerns how entire activity patterns are affected by greater temporal and spatial flexibility in work activities. Components of this overarching question include, but are not limited to: (1) How is work travel, broken down into commuting trips and trips for work-related purposes, a function of different types of flexible working arrangements? (2) How do these effects interact with personal and environmental characteristics? (3) How is non-work travel correspondingly affected? (4) How do workers rearrange their work activities to accommodate other activities? (5) Finally, which technologies are most effective in encouraging which types of arrangements, and, in turn, which types of travel patterns? This last question can provide a hook to policies aimed at encouraging sustainable growth (Camagni, *et al.*, 1998, Nijkamp and Ursem, 1998).

4.4. Self Employment

IT influences go far beyond telecommuting and other flexible arrangements made between employees and employers. In order to cut costs and increase flexibility in rapidly changing marketplaces, businesses have increased subcontracting and other types of outsourcing, which in turn encourages self-employment (Manser and Picot, 1999). New home-based and mobile IT has improved the effectiveness with which self-employed individuals can communicate with clients, suppliers, and collaborators. Women, in particular, are more than ever choosing self-employment and other flexible working arrangements (Boden, 1999).

Giuliano (1998) reports on important differences between full-time, part-time, and self-employed workers in terms of their commuting patterns and residential and work locations. Additional relevant questions for travel behavior are similar to those posited for flexible working arrangements. Also, we should investigate how individuals change their travel behavior as a result of becoming self-employed for the first time. And how do self-employed workers differ from their employee counterparts, in terms of activity and travel behavior?

4.5. Contingent and Part-time Working Arrangements

In some countries, particularly the U.S., new information technology is one of the factors causing increases in the percentage of workers who are engaged in contingent (non-permanent) and part-time work arrangements (Barnasek and Kinnear, 1999; Boden, 1999; Capello, 1994; Manser and Picot, 1999). Advances in IT make it easier for firms to keep track of and integrate the work of non-permanent and non-full-time workers. If part-time workers and full-time contingent workers continue to have shorter commuting times than full-time non-contingent workers, as reported by Giuliano (1998), increases in the relevant size of the part-time and contingent work force could have a moderating effect on peak-period traffic congestion. Giuliano and Gillespie (1997) argue that the greatest effects of IT on travel will be through the “indirect” societal changes involving temporary and short-tenure employment and self-employment, and these effects will far outweigh the influences of telecommuting on travel behavior.

An important factor is the IT economy itself, particularly the Internet portion of the industry. Start-up Internet firms must grow quickly to be successful, and in certain circumstances they must shrink quickly in order to survive. This generates substantial numbers of part-time and contingent hi-tech workers. In addition, the corporate culture of the Internet industry relies on creativity and embraces free-lance (self-employed) professionals. Thus, in the U.S. there are extensive populations of contingent workers in large metropolitan areas and in regions where high-tech firms are concentrated (the so-called silicon valleys, forests, beaches, and hills of the U.S.). Employment of contingent and part-time workers has been traditionally discouraged by most Western European governments and by the E.U., and this difference in labor laws is often cited as one factor in Europe’s lag behind the U.S. in terms of the Internet economy.

4.6. Mobile Working

Closely related to flexible working arrangements is the issue of the impact of mobile IT on work that takes place away from the usual workplace(s) or home (Mokhtarian, 2000). Due in large part to today’s mobile phones and portable SMS (email) and fax devices, many people maintain mobile offices. Others carry on work while commuting between home and their office or remote work site. Commuters can also use mobile communication devices to make more efficient use of their travel time by conducting business and coordinating activities with household members and friends. For the rest of the population, the downside to mobile working is the hazard to road safety caused by drivers engaged in mobile phone conversations, and the disruption to our peace and quiet caused by loud mobile phone conversations in public places, particularly in public transport conveyances and on station platforms. Hopefully, this will be attenuated by new laws and ordinances, and by improvements in manners.

Smart mobile phones and handheld wireless Internet devices will increase the efficiency and pleasure of working while on the move. We can safely assume that mobile workers are presently using telecommunications to optimize their activity and travel schedules,

and future IT developments will improve their ability to do so. Mokhtarian (2000) argues that we need to study how this affects workers' activity and travel patterns. By collecting appropriate data on the use of mobile communication devices, together with corresponding data on activity participation and travel of mobile workers, we should be able to classify types of telecommunication activities in terms of replacement, generation, and management of specific types of activity and travel behavior. Such a classification scheme was used by Claisse and Rowe (1993) in a study of the effects of domestic telephone calls on mobility. Zumkeller (1996)(1997) and Mokhtarian and Meenakshisundaram (1999) demonstrate how communications data can be collected for such studies.

4.7. ATIS for Private Vehicles

Future IT should greatly enhance the potential for effective and user-friendly traveler information. ATIS (Advanced Traveler Information Systems) will be able to take advantage of elegant new Internet technology developed not for the transportation market, but for the much larger market of business-to-business e-commerce. Travelers will be supplied information on traffic conditions and near-term forecasts as well as real-time information on hazards and incidents. Web-based systems could replace existing technology developed directly for ATIS, technology that often doesn't work as advertised or is found by potential users to be ungainly and unattractive. The next generation of the Internet will support intelligent agents that operate on computer-readable XML Internet information content, as discussed in Section 3.2. It will be relatively straightforward to design agents and XML Websites containing real-time information on network performance levels, so that agents can interrogate the network sites and report back on the state of travel conditions. A viable extension is for the traveler's agent to recommend alternative trip routing and timing. Hand-held Internet devices (Section 3.3) will allow travelers to access Web pages and receive reports from smart agents at sites away from home.

If the use of on-board computers is any indication, early adopters of these technologies will likely be commercial vehicle operators. The sharp increase in just-in-time distribution systems begun in the 1980's continues today. Such systems will benefit most from sophisticated dynamic routing systems.

Specialized applications will undoubtedly include providing access information for handicapped travelers, tourists, and anyone with unusual requirements. IT advancements will also improve the efficiency and attractiveness of mobility-sharing programs. Car sharing has flourished in Europe, where in 1999 there were over 200 organizations in 450 cities involving over 130,000 participants (Sperling, Shaheen and Wagner, 1999). Most car sharing involves use of general-purpose automobiles, but some programs involve sharing cars for access to public transport and sharing of alternative-fuel vehicles, or both (e.g., the CarLink Program, which provides cars for access to a rail transit station in the San Francisco Bay Area). IT can facilitate

reservations and billing and can allow clients to check on the real-time availability of vehicles at any given location.

ATIS is only one portion of Intelligent Transportation Systems (ITS) that will benefit from near-term advances in IT. Traveler behavior will surely be affected, and studies such as those of Polydoropoulou, *et al.* (1994), will need to be repeated to test the behavioral effects of travelers easily obtaining more accurate and accessible information concerning route, destination and trip timing. Regarding shopping activities, previous studies (e.g., Kraan, *et al.*, 2000) should be expanded to include online shopping options that do not involve travel at all.

The groundwork for studying the effects of traveler information on travel behavior has been laid in the studies reviewed by Golledge (1997) and Mahmassani (1999). In most cases, these studies need updating to extend their findings to capture the effects that future higher performance ATIS will have on activity and travel behavior. The best way to do this in advance of implementation is to use stated choice experiments to expand the attributes of present information, preferably in combination with revealed preference data available through evaluation of a simpler ATIS project implemented using existing technology (Bates, 1998, Hensher, 1994 and Louviere and Hensher, 2000).

5. POTENTIAL IMPACTS ON COMMERCIAL VEHICLE OPERATIONS

5.1. Business-to-Business E-Commerce

The vast market for business-to-business e-commerce is driving many of the technological developments reviewed in Section 3.2. In particular, the XML language for Web pages and intelligent agents (specifically Java-based agents), are designed to serve future online business needs. Up until the present, much of business-to-business e-commerce has occurred on private specialized networks using what is called EDI (electronic data interchange). EDI functions will likely be integrated within the Internet, as a result of XML and other Internet enhancements (Glushko, *et al.*, 1999). Estimates of EDI transactions may or may not be included as part of all business-to-business e-commerce (EDI is included in Figure 4 data). Including EDI transactions, one source (Boston Consulting Group, 2000) estimates that online business-to-business transactions in the U.S. amounted to US\$ 671 billion in 1998, US\$ 92 on the Internet and US\$ 579 billion using EDI on private networks. By 2003 it is projected that the Internet's share will dominate the EDI's share of more than US\$ 2 trillion in online transactions. The following 1999 to 2003 growth factors are projected: In North America, e-commerce transactions will increase from 7% to 24% of all business-to-business transactions; in Western Europe the growth will be from 3% to 11%; in Asia/pacific it will be from 2% to 9%; and in Latin America it will be from 2% to 7% (source: Boston Consulting Group, 2000).

Soon companies will be using computer-interpretable XML forms for publishing product catalogs, placing orders, making reservations, and scheduling shipments. Intelligent agent with proper authorization will be able to obtain price lists, inventory reports, and schedules, and will even be able to negotiate with other agents to form and reform strategic coalitions to bid on contracts and leverage economies of scale (Glushko, *et al.*, 1999, Maes, *at al.*, 1999). The savings in operating costs are projected to be substantial, on the order of US\$ 1.25 trillion worldwide by 2002 (source: Giga information Group, 2000).

5.2. Structural Changes in the Freight Transportation and Logistics Industry

The demand for freight transportation is already being affected by e-commerce as is the very structure of the freight transportation and logistics industry (The Economist, 2000). E-commerce may lead to smaller, more frequent shipments and significant freight flows from points where neither shipper nor recipient are present. Traditional package pickup and delivery services will be expanded to serve a large portion of the business to consumer shipments and specialized carriers will emerge to support niche markets (grocery delivery for example). Third party logistics providers may be the beneficiaries of the rapid growth of consumer e-commerce; e-merchants typically do not possess and may not wish to develop transportation and logistics capabilities.

E-commerce will generate a much greater role for certain kinds of intermediaries in the distribution business: freight forwarders, brokers, facilitators, agents, etc. Two opposing forces fueled by e-commerce and the information explosion will resist and support the growth of third party services. The first of these, disintermediation driven by the ease of information gathering and sharing made possible via the internet and related technologies, will lead some third parties to fail. When shippers, carriers and consignees can communicate directly, customs brokers, freight forwarders and purveyors of similar value added services will either adjust to changing conditions or will be out of business within a few years. The second force, which will no doubt lead to continued growth among third parties, is disintegration fueled again by information. Companies considering outsourcing logistics services can evaluate their options and make such decisions quickly and with a higher degree of confidence in the past.

While consumer to business e-commerce has received intense attention in the media, business to business e-commerce will likely have a much more significant impact on the freight transportation system. The impact of the revolution in just-in-time manufacturing systems of the 1980's and 90's may pale in comparison with the changes that are to come.

A new breed of logistics service providers is emerging. These are third parties who provide no physical distribution or warehousing services but who broker information to shippers, carriers, warehouseers and "traditional" third party logistics providers. Just a few examples of information provided include pricing, load matching, real-time routing

and the real-time information about the length of queues at intermodal facilities. The list will continue to grow rapidly as these companies rush to come "on-line".

5.3. ATIS for Commercial Vehicles

Commercial vehicle operations will benefit from the advanced traveler information systems developed for passenger transportation. In addition, specialized services for CVO continue to emerge. These services include web based information systems that provide parking information and queue lengths at intermodal facilities. Some important questions about ATIS for commercial vehicles are unanswered at this time. What is the perceived usefulness of these services? What is the role of the public sector in the development and delivery of information systems which benefit the private sector? What benefits to the public experience because of CVO ITS? Will third party logistics providers get into the market of developing and providing ATIS to their partners or customers? How should ATIS be bundled with other information or services?

6. RESEARCH FRAMEWORK

6.1. Personal Activities and Virtual Accessibility

We need to look at the entire activity pattern of an individual, and the interrelated activity patterns of multiple individuals in a household to understand how telecommunications affects travel behavior (Goulias, 2000). Engaging in telecommunications is an activity itself, just as travel is. However, incorporating telecommunications in our activity paradigms requires that we modify our views of time and space. Just when activity modeling is rediscovering the usefulness of the time-space prism concept originally proposed by Hägerstrand (1970) (1975), the concept itself must be updated to account for telecommunications. Time-space prisms can be used to depict the activity locations that are accessible to an individual within a given time period by using projections to the physical plane from the time dimension. The accessible area is defined by the individual's present location, travel speeds in all directions, and the time needed to perform the activity. The type of activity can be recorded on the time axis, allowing daily activity patterns to be traced in time and space. Now, however, distance and its associated time and cost can no longer be viewed as the singular impediment to conducting an activity at a remote location. Many activities can now be conducted using telecommunications devices. This has been true ever since the advent of the telegraph, and later the telephone.³ Now however, shopping, personal business, and work can be electronically performed using visual media such as the Internet from home and from remote locations using new types of mobile telecommunication devices.

³For an historical study of interactions between travel behavior and new communications technology, see de Sola Pool (1983) and de Sola Pool (1977).

To this time-space representation, we should now overlay virtual accessibility to activities that can be performed electronically by persons without changing location. Insights on how to accommodate virtual accessibility can be gained from investigating the time-space concept and the definition of accessibility itself.

Hägerstrand (1970) defined three time-space constraints that can be adapted to the modern world of IT. First is the coupling constraint, which describes a person's commitments to be at certain places at certain times. This is one constraint that is certainly subject to modification due to flexible working arrangements. Activities previously subject to coupling constraints might also be satisfied by replacing personal contact with telecommunications, if a person feels that the activity requires only information and not his or her physical presence. Learning and experience can easily change a person's strength of commitment to coupling constraints (e.g., discovering whether use of a mobile phone is a satisfactory replacement for making a trip to talk with someone in person). Axhausen (1997) argues that feeling and perceptions regarding coupling commitments should be collected as an integral part of activity surveys. We need empirical data to determine which activities people consider to be physically and electronically substitutes, as well as which activities they consider to be physical and electronic complements.

Second is the capability constraint, which captures the ability of a person to overcome spatial separation given the resources available at any point in time. One obvious factor affecting capability is the presence or absence of a vehicle such as a car or bicycle. Other factors, such as the ability to use public transport, are based on knowledge and experience which varies from person to person (Axhausen, 1997). Now we must introduce factors affecting telecommunications capability, such as connected computers and other Internet appliances at home and work, and mobile phones and handheld Internet devices at remote locations. Once again, knowledge about what can be accomplished using such information technology is critical. Demand models need to be sensitive to perceptions of accessibility, and survey instruments need to be designed to elicit perception data.

Finally, Hägerstrand's (1970) third constraint involves authority, which defines time-space zones of opportunity and exclusion, including performance schedules and opening hours. Here again is another metric in which to capture opportunities presented by information technology. People who are cognizant of e-commerce opportunities might engage in online shopping or personal business at times when bricks-and-mortar businesses are closed. Again, perception of capability might be as important as actually having access to telecommunication devices. It is apparent that interactions involving travel telecommunications need to be viewed in a context of activity patterns over multiple days.

Information technology also dictates that travel behavior researchers revisit their definitions of accessibility. Geographers define accessibility to be a measure of the strength and extensiveness of spatial relationships between opportunity seekers and relevant opportunities. Level of accessibility for an opportunity seeker is a function of (1) the total number of relevant opportunities, (2) the spatial distribution of these opportunities, (3) the spatial location of the individual, and (4) the individual's ability to overcome spatial

separations. Shen (1999) (2000) argues for dividing opportunities into three mutually exclusive types for purposes of measuring accessibility: (a) opportunities that can be accessed only through telecommunications and are thus available only to persons with telecommunications capabilities, (b) those that can be accessed either by transportation or by communications, and (c) those that can be accessed only by transportation (i.e., those that require the commitment of physical coupling). IT should be viewed together with the transportation system as a form of spatial technology that influences accessibility (Coucelis, 1995, 1996).

6.2. Technology Adoption by Individuals and Households

We will also need to develop analytical tools to forecast individual and household choices of information technology, particularly choices of home-based and mobile Internet communication devices. Transportation researchers are armed with sophisticated choice modeling methodology (reviewed by Bhat, 1997 and Brownstone, 2000). Moreover, we have the capability to use stated choice methods to extend choice models estimated on actual (revealed) choices to levels of attributes unavailable in existing choice sets (Louviere and Hensher, 2000).

Personal choices of activity patterns will become ever more intertwined with choices of information technology. Even in our current travel demand models, where IT is not considered, we often need to recognize that availability of choice alternatives is dependent upon access to mobility resources (e.g., car availability or public transport season tickets) and access to information (e.g., knowledge about public transport routes and schedules, or knowledge about alternative routes). In the new world of IT, activity choice alternatives are a function of access to information technology (e.g., home-based or mobile internet connectivity) and knowledge about how to use the technology for activity scheduling. This mutual causality could be captured by joint models of demand for IT technology and activity patterns, because activity patterns are a function of IT availability, while demands for IT are probably a function of demand for certain activity patterns. Similar joint models have been formulated for car ownership and activity demand (e.g., Golob, 1998).

Household decision making regarding information technology is similar in some ways to household decision making regarding automobile ownership. They both deal with shared household resources, but the choice object is typically used most by only one household member. Mobile communication devices are sometimes shared but often used almost exclusively by one household member, so generally decision making for this technology can be approached on an individual basis, with household parameters. When we are addressing choices involving technology that is well entrenched at the time, such as PC's with modem Internet connections or cellular phones today, we can probably collect revealed preference data using random samples. In cases of advanced technologies, such as handheld Internet devices, we will need to employ choice-based sampling. We should also expect high degrees of population heterogeneity in all technology choice models, due to strong age and lifestyle cohort

and spatial effects. Such heterogeneity might be captured by interaction terms involving situational variables (such as age group, income, occupation, and location dummies) and choice-specific constants and attributes of the choice alternatives.

Choices of telecommunications activities can be integrated into activity-based models. Examples of modeling frameworks that are conducive to extensions to virtual accessibility include, but are not limited to, Ben-Akiva and Bowman (1998), Bhat and Misra (1999), Bowman and Ben-Akiva (1998), Golob (2000b), Golob and McNally (1997), Kitamura (1984), Lu and Pas (1999), Mokhtarian (1998), and Yamamoto and Kitamura (1999).

Insights into relationships between telecommunications and activity participation can also be gained through exploratory analyses of time use data (Goulias, 2000, Lee, 1999, Massot, 1997, Mokhtarian, 1990, and Zumkeller, 1997). Market research firms serving the IT industry constantly produce statistics about telecommunications use, particularly Internet use (e.g., Ernst and Young, 1999). Demographic and spatial trends in general telecommunications use can guide studies of impacts on travel and activity behavior.

6.3. Commercial Vehicle Operations: Shipper, Carrier and Firm Behavior

The impacts and information technology on the freight transportation system provides interesting opportunities for research. Technology adoption itself was addressed earlier in section 2. Of keen interest is how shipper carrier and firm behavior will be affected by Information Technology. Shipper behavior research has typically addressed the following: mode choice, the private versus for-hire carrier selection process, shipper carrier relationships and carrier selection criteria and more recently, the role third party logistics providers. Behavioral studies of the freight transportation industry should be revisited in light of the rapid changes resulting from information technology adoption.

A review of freight demand and shipper behavior research is found in Regan and Garrido (2000). Thorough reviews of mode choice research are provided by Evers, Harper and Needham (1996) and Murphy and Hall (1995). The study by Evers *et al.* is based upon a survey of shippers in the state of Minnesota, in the United States. The shippers were asked to rate intermodal, rail and motor truck transportation on seventeen service characteristics. Factor analysis was used to load twelve of the seventeen service characteristics onto six factors. These were the same factors used by McGinnis (1990) in an earlier study. The factors included the following: timeliness, availability, suitability, firm contact, restitution and cost. Their study found that timeliness and availability informed overall shipper perception of each mode than the other four factors. A follow up study conducted by Murphy and Hall (1995) used the same factors as the earlier McGinnis study too. That research extended the McGinnis study but ended with essentially the same conclusions: 1) that shippers value service and reliability relatively higher than cost and 2) that the shipper mode and carrier choice

decision process has not been heavily affected by the 1980 deregulation of the trucking industry in the United States.

Several studies have had as their focus the impact of just in time (JIT) manufacturing and distribution systems on transportation choice. Lieb and Miller (1988) surveyed over one hundred corporate directors of transportation/logistics in what were then the 500 largest manufacturing firms in the United States about the impact of JIT manufacturing processes on the transportation function. Their study found that JIT processes led to increased selection of contract, air and private carriers, little change in the selection of common carriage (as a mode -- individual carrier selection appears to be significantly affected by JIT) and a sharp reduction in the selection of rail transportation.

6.4. Carrier Selection and Shipper-Carrier Relationships

Several factors have led to a change in recent years in shipper carrier relationships. JIT manufacturing and distribution systems made possible by advances in technology have led companies to include their suppliers (both internal and external) in their production processes. The extent to which this has led to changes in their relationships with carriers is examined by Lieb and Miller (1988). Based on a survey of corporate transportation managers they concluded that JIT implementation substantially affects the criteria by which carriers are selected, increases shipper-carrier communications (and communications needs), reduces the number of carriers used and led to mode choice changes which favor truck only and truck-air transportation over truck rail services. In a similar study, Crum and Allen (1990, 1991), examined the impact of logistics strategies adopted to cope with the demands of JIT systems on shipper carrier relationships. Strategies examined include carrier reduction, the use of EDI and the use of long term contracting for motor carrier service. Their study found that shippers were increasingly entering into "partnershiping" relationships with their carriers and that many US carriers received more than thirty percent of their revenues from a single key shipper. When they revisited the industry a few years later they noticed a continued move from transactional to contractual relationships (Crum and Allen, 1997). Larson (1998), examined carrier reduction resulting from the implementation of information technologies, primarily EDI. He found that carrier reduction leads to better customer service, less loss and damage, more reliable (on-time) delivery, and lower total logistics costs. Levels of shipper/carrier mutual trust increase as shippers develop stronger relationships and increased interdependence with a smaller number of carriers.

6.5. The Growth in Third Party Logistics

There has been considerable interest worldwide in last few years in the growth of third party logistics (3PL or TPL) providers. These firms typically provide some of the following services: warehousing operations, freight payments and auditing, carrier selection and rate negotiations. In addition, 3PL firms may develop information systems and manage inventory and customer order fulfillment (Boyson *et al*, 1999). The rapid

growth of global markets has been followed by the birth of strategic channel intermediaries, such as foreign freight forwarders, non-vessel-owning common carriers, trading management companies, customs house brokers, export packers and port operators. Several recent studies have addressed the issue of growth in the 3PL market in detail. A study by Murphy and Poist (1998) provides a review and synthesis of research on this topic. They define third party logistics (3PL) services in the following way: "a relationship between a shipper and third party which, compared with basic services, has more customized offerings, encompasses a broader number of service functions and is characterized by a longer-term, more mutually beneficial relationship." Their study suggests that while current use is fairly low (they report that eighty-five percent of users of these services spend less than four percent of their corporate revenues on third parties) that the majority of users of 3PL services will increase such use in the near future.

Recent studies performed in Europe in the same period report that market growth has not been as rapid as was predicted in earlier studies (for example, Virum, 1993). Parker (1999) reports that while European users of 3PL services are satisfied with services received that they have not, in general, increased their use of such services during last few years. However, many have increased the breadth of services purchased beyond warehousing and transportation. Berglund *et al* (1999) suggest that there are several indications that the 3PL industry has not reached maturity. The indications they present are that there are still a large number of 3PL providers, suggesting no clear market leaders, there exist an absence of a unique and undisputed terminology (even defining the 3PL industry itself), and that there are few market players that concentrate exclusively on 3PL, most are subsidiaries of large transportation companies.

Lieb and Randal (1999) discuss insights gained from a multi-year survey of chief executive officers of the largest 3PL providers in the United States. Key findings reported in the paper are the following: most of the companies surveyed are autonomous subsidiaries of companies in the transportation and warehousing business; most have significantly increased their international operations in the past few years; most are increasingly forming strategic alliances with other 3PL companies, and companies primarily involved in warehousing, trucking, freight forwarding, and customs brokerage. That study followed an earlier study by Lieb (1992) which had as its focus large manufacturers, the users of 3PL services. Similarly, Leahy, Murphy and Poist (1995) examine the determinants of successful third party relationships from the provider perspective. Twenty-five potential determinants of success are examined. Among these customer orientation and dependability emerged with the highest importance ratings. More recently, Sankaran and Charman (2000) performed an exploratory study of the effectiveness of 3PL contracts as well as the process by which buying firms purchase services. Creative contracting may emerge as an increasingly important topic in the study of shipper behavior.

The benefits of outsourcing logistics services in some cases can be very significant. 3PL's have made "build to order" manufacturing systems possible in the computer industry where there would have been otherwise infeasible (Harrington, 1999). The

question of how companies select providers of third-party logistics services was recently addressed by Menon, McGinnis and Ackerman (1998). Their main insights are based on an analysis of a survey of logistics managers and subsequent factor analysis. They found that the primary factors in the selection process are suppliers' perceived performance and suppliers perceived capability. They found that respondents were less concerned about the prices charged for services. Their study points out that the purchasing decision for 3PL services should be viewed like any other purchasing decision and that companies should begin the process by carefully documenting performance and quality requirements in a scope-of-work document.

For the specific case of less than truckload (LTL) firms providing third party logistics services, Hanna and Maltz (1998) examine two separate outsourcing decisions. First they examine the extent to which shippers are turning to carriers for increased offerings. Then they examining the carrier "purchase or build" question related to providing such services themselves or contracting with a third party to provide warehousing services. The study, which included interviews with the majority of large US LTL carriers found that most were offering warehousing services and that large carriers were providing the services directly rather than trusting third party providers for warehouse management.

Quantitative analyses of the third party logistics industry are uncommon. One exception is provided by Fridstrøm (1998). That study involves two stated preference (SP) experiments undertaken on a sample of 300 wholesale firms in Norway, both at strategic and operational levels. The SP data were analyzed through binary logit models. The models allowed the analysts to draw several conclusions about shippers' behavior. For instance, different values of travel time (willingness-to-pay for marginal freight transportation savings) were derived for time savings versus delays—i.e. whether transportation time is decreased or increased. The latter is not surprising because it is in accordance with intuition; however, the quantitative approach followed by the author allowed the estimation of numerical values for that particular market. The derived value of time differed by commodity type but not by shipment size or value.

This discussion of the 3PL industry is concerned mainly with decisions made by shippers in established companies and established industries. There are indications that the emergence worldwide of e-commerce may lead to an order of magnitude increase in business for 3PLs. These companies are setting up shop quickly and in some cases outsourcing all of their logistics and transportation functions (Foster, 1999, *The Economist*, 2000).

7. DATA NEEDS

7.1. Household Activity Surveys

Household travel surveys have evolved from trip-based to activity-based (Goulias, 2000, Lawton, 1997). However, the concerns of the agencies that fund these surveys (the

metropolitan or regional planning organization, or the transportation department of a state, provincial, or federal government or union of governments) remain with trip making. Most household travel surveys collect very little or no data on in-home activities. The collection of in-home activities and telecommunication activities both in- and out-of-home has been judged, up until now, to be too costly in terms of effects on nonresponse and data collection expense. Recent guidelines for household travel surveys (Griffiths, *et al.*, 2000) and travel demand forecasting (Bhat and Lawton, 1999) barely mention telecommunications. Eventually, this will change, and practitioners will come to realize that most household travel survey data collected to date will be of little use in forecasting impacts of telecommunications on travel.

Several recent studies reveal that it is not difficult to add in-home communication activities to household travel surveys (Zumkeller, 1996, 1997, Claisse and Rowe, 1993, and Mokhtarian and Meenakshisundaram, 1999). Communication activities, which today include phone calls, faxes, emails, and Internet contacts, can be registered in terms of their type, purpose, duration, location, and send or receive mode. Types can be broken down into face-to-face meetings, transfer of physical objects (by hand delivery, mail or package delivery), and telecommunication. Internet contacts can be subdivided according to the nature of the contact (e.g., information retrieval versus transaction).

The parts of household activity survey dealing with personal and household data also need to be expanded. In addition to the usual mobility data on car ownership, parking permits, and public transport season tickets, we need to know what access individuals have to various information technologies. These should include fixed and mobile PC's with Internet access, including small devices, such as personal digital assistants, and wireless devices, such as cellular phones and handheld Internet devices. For household members in the work force, including self-employed individuals, we need to know the details of their working arrangements: their work schedule, their work locations, whether the present working arrangements are permanent or not, and what telecommunications and other job-related equipment or facilities they have at their home or remote work site.

7.2. Surveys of Commercial Vehicle Operators and Shippers

The impact on the highway system of ongoing technology-driven changes in manufacturing and distribution systems is not sufficiently well understood. Reliable freight demand models are few and far between. Moreover, these models, when they do exist, often fail to identify key issues driving mode and carrier choice. Freight movements to support manufacturing and distribution should be segmented by time sensitivity and examined by segment. In order to identify policy initiatives which will lead to the development of a satisfactory and sustainable freight transportation network we must first understand the needs of shippers. Shipper surveys can provide data for estimating models of mode and carrier choice that are sensitive to factors including

transit time, reliability of transit time, scheduling accuracy, scheduling timeliness, scheduling flexibility, load security, and any other factors.

7.3. Internet Surveys

Data on both personal travel behavior and commercial vehicle operations can be collected over the Internet. Internet usage surveys are common in the Internet industry. One ongoing survey to monitor Internet usage consists of a panel of 3,000 persons who access the Internet at home and at work (Coffey, 2000). There are other similar panels. Typically, respondents chosen at random are asked to install software that will automatically monitor their computer usage. The software is also used to “pop up” and record who in the household (or at a workplace) is using the computer during a session. There are also Internet surveys in which users log onto a survey Website and complete a questionnaire. Internet survey software is readily available (e.g., Perseus, 2000).

In travel behavior research Internet surveys represent choice-based sampling of a new kind. We are familiar with the statistical and practical issues involved in sampling based on travel mode (e.g., transit on-board surveys) and destination or route (journey intercept surveys). While some have dismissed Internet and other multimedia survey methods as being inappropriate for general-purpose household surveys until there is more widespread household connectivity to the Internet (Griffiths, Richardson and Lee-Gosselin, 2000), Internet surveys can provide important data for dealing with interactions between e-commerce and activity and travel behavior. Surveys of activity and travel behavior could be coordinated with ongoing Internet market research surveys, or travel behavior researchers can develop their own, aided by experiences gained elsewhere (Plaxton, *et al.*, 1999).

Choice-based samples require independent information regarding market shares in order to correctly estimate the standard errors of coefficients and to correct choice-specific constants for forecasting purposes. In Internet and other telecommunications-based surveys, this requires information about the penetration and use of the telecommunications technology (e.g., Internet connections) within a given territory. To date, most transportation planners have not sought to include any of these kinds of data in their inventory, and a recent discussion of future transportation data needs makes no mention at all of telecommunications data (Limoges, *et al.*, 2000). If we are to make inroads into understanding telecommunication impacts on travel, these data will be needed.

7.4. Panel Surveys

Panel surveys are an effective way of shedding light on IT impacts on personal travel. Such surveys (reviewed in Golob, *et al.*, 1997, Kitamura, 1990, Ma and Goulias, 1997) is useful in isolating learning behavior, cohort effects, and exposure to opportunities, all of which are of importance in the acquisition and use of information technologies. An

example is the age cohort effect on computer literacy. The dynamics of activity behavior can also be important. For instance, with panel data we can study whether workers who change working arrangements change their travel behavior in such a way that emulates cross-sectional differences between workers in their former and present states, or whether their travel patterns evolve differently, depending on history and cohort.

We can gather valuable data using panel surveys to capture the travel impacts of new IT technology. Panels could be implemented to measure activity and travel behavior before and after the launch of a new communication device, such as a new type of handheld Internet device, or before and after the launch of new e-commerce opportunities. Control samples are needed in all such before-and-after studies. It should be possible to persuade companies marketing IT products and services to provide samples and even financial support, in exchange for timely information concerning research results. However, such studies of IT impacts on travel and activity behavior require quick-response data collection. If it takes two years to design, implement, code and check the data before they are ready for analyses, that is too long. Information technology is advancing too fast. With slow-maturing data of the type we are familiar with in travel behavior research, we will end up studying effects that are no longer relevant.

Panel surveys of commercial vehicle operators would provide policy makers with important input but that industry segment. Limited panel surveys have been performed of small segments of the industry over the years but these have typically focused on management issues rather than transportation itself.

8. POLICY IMPLICATIONS

Transportation planners and policy makers should not miss the rich opportunities presented by IT. Many persons are likely to use telecommunications to eliminate certain types of distasteful travel, or to reschedule and reroute trips to less congested times and places. People have proven to be very ingenious in avoiding congestion and other psychological and economic costs associated with travel (generally being more ingenious than their travel behavior modelers). For instance, consumer e-commerce must be reducing peak holiday period congestion at shopping malls and on commercial streets in the U.S., but we have no reliable measure of this impact. The incidence of contingent, part-time and self-employment, to some extent increased by IT developments, must be reducing peak commute travel, but again we have very little quantifiable evidence of this impact.

Perhaps partly because it is considered a “non-problem,” policy implications of IT impacts on travel have received little attention. Only telecommuting has been looked upon as a means of reducing travel, often with unrealistic expectations (as pointed out by Salomon, 1996 and 1998). If travel behavior researchers can identify which

technologies are most effective in reducing travel without undesirable side effects, this should be of great value to planners and policy makers, even if they have no appreciation of that value at the present time.

In terms of the built environment, planners and policy makers need to be aware of the potential effects of e-commerce on the vitality of commercial areas (Batty, 1996, 1997). The vitality of neighborhood stores may well depend in part of whether such stores can compete with large chains in terms of online access and delivery services. Gould and Golob (1999) argue that one way in which neighborhood stores, particularly those in the vicinity of public transport stations in residential communities of large metropolitan areas, can take on a new life as pick-up locations for food items and other household goods ordered online during the day by workers. Architecturally, there is even a new movement to design “cybrid” shopping environments, in which a commercial building and a Website is viewed as a single package, creating resemblances between real and digital environments that can help employees and shoppers alike find products and services easily (Novitski, 1999).

The virtual accessibility supplied by the Internet can be most appreciated by persons with low levels of conventional accessibility. Presently, the highest Internet use per capita is in countries with either long, dark winters (e.g., Iceland, Finland, Norway, Sweden and Canada), or with isolated rural communities (e.g., parts of Australia, Canada and the U.S.). New demand for connectivity is likely to come from isolated areas of developing nations. In addition, social benefit can accrue from extending virtual accessibility through Internet connectivity to handicapped, elderly and economically disadvantaged populations.

Most all modern IT developments are market-driven. Government intervention is not needed, and, importantly, not desired. However, that does not mean that regional and local government planners and policy makers should not be concerned about the impacts of IT on the accessibility of population groups, on land use, and on the timing and location of flows on their transportation networks.

9. CONCLUSIONS

To date, very little relevant research has been conducted, and most of the research that has been conducted has focused only on one aspect related to IT: telecommuting. We must do better than that in order to keep our field relevant to planning and policy making. Travel behavior researchers ignore the impact of IT, particularly the impact of the Internet, at their peril. The effects of future IT on travel behavior is currently unknown, but we can be sure it will be substantial.

Not since the introduction of the automobile age has transportation been faced with technological impacts of this scale. Telecommunications are just beginning to permeate almost every aspect of our lives. As we become busier, we will increasingly rely on IT

to avoid unnecessary travel. As populations increase, particularly populations within metropolitan areas, we will also increasingly rely on IT to avoid congestion on transportation networks and at activity sites. Also, as we spend new time engaged in telecommunications, there will simply be less time available for other activities, including travel. Small effects by a very large number of persons will aggregate up to large effects on a system-wide basis.

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