TELECOMMUNICATIONS AND TRANSPORTATION INTERACTIONS: A REVIEW[*]

by Metin Senbil[**], Akimasa Fujiwara[***] and Junyi Zhang[****]

1. Introduction

Before 1980s, all of the telecommunications sectors of the advanced economies were under a state monopoly as there are significant economies of scale originating from huge initial sunk cost that has to be spent for the infrastructure and then negligible marginal costs in order to deliver the service and maintain the infrastructure. But despite economies of scale in production, governments realized that competition may improve the consumer welfare by improved services and reduced prices (Crandall, 1997; Shy, 2001). Consequently, many economies in the developed countries liberated and deregulated (and where applicable, also privatized the state owned monopoly firm in) the telecommunications sector. Market entrance conditions are significantly eased in order to increase competition and hence efficiency in the market (Cairncross, 1997). Widespread privatization, deregulation and liberalization in the telecom industry resulted in opening up local, long-distance, international, cable and cellular telephone markets in many countries. Services increased while prices decreased and competition ruled sector witnessed the spread of different products powered by new technologies and new products quickly diffused in the market.

In the last twenty years, the use of telecommunications changed significantly. Although the adoption (or use) of telecommunications have changed the ways of space-time management (see Pool, 1983 for an historical account), the new telecommunications, which hosts many applications of information and telecommunications technologies (ICT) have changed the total travel demand by being utilized in many different and various ways. In this regard, the relationships between telecommunications and transportation is said to be exploded in the last two decades (Graham and Marvin, 1996). This is mostly because of the sectoral changes, by which most of the telecommunications sectors in the advanced economies grew and expanded remarkably (Ishikawa and Nishimura, 1998, Nemoto and Asai, 2002; Vogelsang, 2003).

In the last thirty years, the researches that investigate the relationships between telecommunications and transportation have increased hand-in-hand with the products and services in the market. The collection of researches on the interactions between telecommunications and transportation can be classified with respect to three waves complying with the past three decades. The first wave has been emerged mostly because of the worries about the oil consumption over increased prices. The second wave of studies generally concentrated on the technological shifts brought by new products and possible convergence of the wireless and wired communications services. However the availability of the technological advances to the general public was poor and most of the services are mentioned as premium services during these years. The studies of the 80s generally relied on the assumptions of the availability of these services in the future. The 1990s witnessed revolutionized (liberated, deregulated and privatized) telecommunications sectors in most of the advanced economies that made most of the services available at marginal costs to the general public. Thus, the market penetration of most of the services has allowed testing of the strong hypotheses made earlier especially substitution of the trips by information signals. Nowadays the researches have been evolving into that direction.

2. Historical Development

Apart from the historical development of the studies in time, it can be said that the studies based on telecommunications and transportation interactions can be classified with respect to a.) tele*plus* phenomena: use of telecommunications in order to conduct certain activities, e.g., telecommuting/teleworking, teleshopping etc. b.) input-output relations: inputs-output relations between transportation (e.g., supply of right of ways for wired telecommunications services by transportation network) and telecommunications (e.g., ITS, transport logistics and operations made available by telecommunications). c.) space-time effects: the use of telecommunications as a space time as well as activity-travel management tool. In this part we will review some of selected studies that falls in one of these classifications. Selected reviews of studies on telecommuting (teleworking),

---

[*] Keywords: telecommunications, transportation, teleplus services, activity travel demand.

[**] Member of JSCE, Dr. Eng., Graduate School of International Development and Cooperation, Hiroshima University, (Kagamiyama 1-5-1, Higashi-Hiroshima, JAPAN 739-8529; Phone and Fax: +81-82-424-5970; e-mail: senbil@hiroshima-u.ac.jp)

[***] Member of JSCE, Dr. Eng., Graduate School of International Development and Cooperation, Hiroshima University, (Kagamiyama 1-5-1, Higashi-Hiroshima, JAPAN 739-8529; Phone and Fax: +81-82-424-6921; e-mail: afujiw@hiroshima-u.ac.jp)

[****] Member of JSCE, Dr. Eng., Graduate School of International Development and Cooperation, Hiroshima University, (Kagamiyama 1-5-1, Higashi-Hiroshima, JAPAN 739-8529; Phone and Fax: +81-82-424-6919; e-mail: zjy@hiroshima-u.ac.jp)

teleshopping (*e*-commerce) and teleconference are given first. This section ends with a review of studies on space time management interactions.

Telecommuting coined by Jack Nilles on 1973 or teleworking, which means working at home or a distant location from the usual work place is heavily investigated since 1970s because of the prospective effects on alleviating or changing the pattern of the work commutes. Glover (1974), Short (1975), Nilles (1975) and Nilles et al. (1976) are the early researches on telecommuting or teleworking. Most of studies in 1970s were forecasting the future by the basis assumption of economical and societal transformation of the advanced societies from industrial to post-industrial societies and drawing inferences on .the future organization of the working life and the working places. But later, Salomon (1984) having a critical look on past studies that derive energy savings, pollution and congestion decrease from telecommuting called for more comprehensive approaches are needed. According to Salomon (1985), substitute for work activity would not be realized immediately after technology is made available because of the "complex issues at play" (p.223) and concluded that a second type of remote work, "neighborhood work center" comprise more realistic choice as social, psychological and legal problems associate with working at home" (p.224) are solved to a large extent. If this type of center-based telecommuting prevails, then Balepur et al. (1998) reports that both person miles and vehicle miles traveled decreases on the days of center-based telecommuting although the number of vehicle trips increases on these days. Mitomo and Jitsuzumi (1999) estimate a significant decrease in congestion in Tokyo (Japan) and cost savings in public transit based on three scenarios similar to those in Nilles (1988). Garrison and Deakin (1988) draw a broad perspective of effects of telecommunications on organization of work and workplaces. Nilles (1988) concentrates on trip reduction that is drawn from several scenarios telecommuting patterns (low, moderate and high penetration of telecommuting among prospective workers) in the workforce. It should be noted that the adoption of telecommuting in the economy in most of the telecommuting studies till the end of 1980s does not report on any of the estimation methods in the future work force estimation and the proportion of the teleworkers. Hamer et al (1991) studied mobility effects of teleworking on Dutch households. They conducted a panel survey consisting of five waves (the first one during non-teleworking periods as the base, and the rest during teleworking periods) on every 3 months starting from March 1990 and ending in March 1991. Hamer et al. concluded that teleworking resulted in significant decreases in trips by teleworkers and peak hour travel has been reduced significantly.

Salomon (1985) argues that shopping is amenable to substitution by telecommunications to the extent that individuals are occupied by other activities and are not different from making shopping "by touching the apple" by telecommunications. Although shopping activity substitution would create trips for distribution systems, they would be more efficient than personal travel (p.224). But when transfer of information and money is required, most of the operations can be done by using telecommunications. On the other hand, telecommunications cannot substitute activities that requires specialty and bears a coupling constraint at the required location such as visits to dentist or hairdresser. One of the earlier studies on teleshopping (lately *e*-commerce) is Salomon and Koppelman (1988) which gives a detailed framework of a choice process of teleshopping versus teleshopping. Gould et al. (1998) distinguished motivations behind shopping into two: purchasing and shopping and looked into the relationship between shopping and shopping trips, especially by car. They established a model that is comprised of structural relations between subsistence activities (i.e., work), maintenance activities (split into two in order to observe shopping activities, i.e., maintenance activities and shopping activities) and discretionary activities. They applied structural equations and analysis of variance with respect to null hypotheses that 1.) among working women, travel time savings due to teleshopping, would not increase maintenance and discretionary activities outside the home, 2.) the amount of shopping time will be the same between teleworkers and other workers, and 3.) the amount of travel time for shopping will be the same between teleworkers and other workers. Results of the analysis turned out to reject the null hypotheses; it was found that working women allocate some of the time savings to types of out-of-home activities mentioned in the first hypothesis, teleworkers spend more time shopping, and they travel more for shopping.

As the information technology and the organization within the cyberworld has been improved significantly in recent years, and the teleshopping evolved into *e*-commerce, which has three different modes, i.e., business to consumer (B2C), business to business (B2B) and consumer to consumer (C2C). Each of these different modes requires a different organization of activities and logistics as well as information infrastructures. Two studies that investigate B2C are Visser and Lanzerdorf (2004) and Mokhtarian (2004). Visser and Lanzerdorf (2004) investigates the activity and travel choices of individuals at the household level, the logistics of firms at the supply-chain level and the location, lifestyle and the network decision of these actors in a wider context of changing patterns of access and locations. According to Visser and Lanzerdorf (2004), there are four groups of b2c consumers, i.e., young adults, the elderly, time pressed and "active-on-the-go" type of people. Adapted from Salomon (1983) the framework used in the study distinguishes the effects of *e*-commerce on mobility and locations on a time scale ranging from short to long term. It is devised that in the short term non-work activities are subject to change, while in the middle term, residential and work location as well as car ownership decisions are subject to change. In the long run, the family formation and work force participation are subject to change because of *e*-commerce. On the other hand, effects on businesses are devised to exist in demand structures, distribution systems, logistics and spatial structure of the businesses. Because of e-commerce, the distribution systems will depend on one piece delivery and non-specialized, heterogeneously loaded small trucks, which make many stops in residential areas. Regarding this change in new distribution systems brought by e-commerce, it is highly probable that vehicle miles of distribution systems will increase in the future. Mokhtarian (2004) discusses, at a

conceptual level, a number of issues related to the evaluation of the transportation and spatial impacts of *e*-shopping. After reviewing the comparative advantages of store shopping and e-shopping, The study is concluded that neither type dominates the other. Future shopping-related changes in transportation are assumed to materialize as the net outcome of four different fundamental causes, that can be viewed hierarchically: (1) changes in shopping mode share keeping the volume of goods purchased and per capita consumption spending constant; (2) changes in the volume of goods purchased, keeping per capita consumption spending constant; (3) changes in per capita consumption spending, independent of demographic changes; and (4) demographic changes. Some factors result in reduced travel while others lead to increased travel. The combined net outcome of all factors will likely to increase travel (complementation).

Mokhtarian (1988) focused on teleconferencing that was adopted by the Southern California Association of Governments (SCAG) in order to improve committee meetings in terms of attendance, representativeness, travel and time costs. An empirical study was conducted based on a survey of participants of these committee meetings. By tabulating round-trip distances of meeting trips for the case of the baseline (non-teleconferencing option) and the teleconferencing sites (two sites within the California State University System. One in Los Angeles, 12 miles from the headquarters, and one in Long Beach, 35 miles from the headquarters), Mokhatarian (1988) found that the average travel distances decreased by about 21% from 61 miles to 48 miles. On the other hand, it was also found that as participation in teleconferencing increased, average vehicle miles traveled increased by about 29% from 854 miles to 1104 miles. Nonetheless, Mokhtarian (1988) argued that improved communications can outweigh any negative impacts on travel and that, although travel may be increased by teleconferencing, it may be redistributed in a manner that may flatten the peak hour congestion levels.

Apart from tele*plus* phenomena, there appeared studies of general relationships between telecommunications and transportation. Studies of Pool (1977a, 1977b, 1982 and 1983) are important studies on telecommunications affects on society. There have been considerable theoretical efforts (the most notable are Salomon, 1985; Salomon, 1986; and Mokhtarian, 1990) in the field of travel demand analysis to conceptualize the relationships between transportation and telecommunications. The general interrelationships between transportation and telecommunications are grouped into: substitution, complementation, modification and neutrality. Substitution refers to the reduction in the use of one by the use of the other, e.g., a telephone call would eliminate a trip for a face-to-face contact by making a trip unnecessary. Complementation refers to the increase in the use of one by the use of the other, e.g., a telephone call would cause a meeting for dinner. When the use of one system changes some features of the use of the other system, this means modification, e.g., information retrieved about road network conditions would change the timing of a trip. Neutrality refers to the mutual independence of the use of the two systems. This typology can be referred to as SCMN typology (note that SCMN stands for **S**ubstitution, **C**omplementation, **M**odification and **N**eutrality conditions).

A general empirical study into the relationship between the use of telecommunications devices and travel can be found in Claisse and Rowe (1993), which classified telecommunications and transportation interactions into: management, substitution, induction and autonomous telephone traffics. This typology is consistent with the SCMN terminology. For telephone calls, Claisse and Rowe (1993) supplied an exhaustive typology based on telephone call “actions” and call “aims”. According to this typology, there can be at least 176 situations in which telephone calls are made. Mokhtarian and Meenakshisundaram (1999) based their research on the SCMN typology and used structural equations modeling techniques with two waves of panel data. The frequency of the use of different communications modes, i.e., the weekday average number of communication incidents made by telephone, fax, e-mail, information objects such as documents, or personal meetings and trips are used as endogenous variables. Exogenous variables included socio-economic variables such as occupation, age and household size. There are two models of structural equations, viz., direct effects model and endogenous-only effects model. The direct effects model contains both exogenous and lagged endogenous variables. In the endogenous-only effects model, on the other hand, the variables consist of endogenous variables, season dummies, and elapsed time between two observation points. Results of the models revealed that own mode effects, which mean the effect of one mode on itself, increased the most with e-mail and the least with personal meetings. This result supports the positive externality of telecommunications. Second to e-mail communications is found to be personal trip category. The study is concluded with the presence of complementarity, rather than substitution, between different communications modes. Golob and Regan (2001) emphasize the need to couple an accessibility measure that covers information and communication technologies (ICT) that might help to understand the physical mobility better. Wiegman et al. (2003) differentiate between short-term direct effects and long term and indirect effects between telecommunications (note that in the study ICT is used). In the short term it is devised that the effects of telecommunications on mobility can be observed directly but in the long term the effects are observed over changing trends and conduct. The authors hypothesize that mobility tends to decrease by short-term effects and increase by the long term effects.

3. Further Research

The telecommunications which is the backbone of ICT has been changing so fast and improving in many respects. Thus the conclusions of most of the past researches have become outdated. We observe more reliable studies that base their projections on readable lines of empirical estimations on the adoption of tele*plus* phenomena have started mostly in the 1990s and increasing nowadays. But the question of the spillover effects of the changes on space time constraints brought by tele*plus*

phenomena probably still remains as an interesting area of future research. Thus researches on space time resolutions of telecommunications and activity relationships are needed. Senbil and Kitamura, 2003a and 2003b are two of the first attempts to devise a holistic approach to the relationships between telecommunications and activities. But these studies address daily activities and the use of telecommunications not for tele*plus* services specifically. The lines of researches have to be merged to address all kinds of spillover effects.

References

1) Balepur, P. N., Varma, K. V., Mokhtarian, P.: Transportation impacts of center-based telecommuting: interim findings from neighborhood telecenters project. Transportation, 25, pp. 287-306, 1998.
2) Cairncross, F.: The Death of Distance, Boston, Massachusetts: Harvard Business School Press, 1997.
3) Claisse, G., and Rowe, F.: Domestic telephone habits and daily mobility, Transportation Research A, 27, pp. 277-290, 1993.
4) Crandall, R. W.: Are telecommunications facilities "infrastructure"? if they are, so what?, Regional Science and Urban Economics, 27, pp. 161-179, 1997.
5) Golob, T. F. and Regan, A. C.: Impacts of information technology on personal travel and commercial vehicle operations: research challenges and opportunities, Transportation Research C, 9, pp. 81-101, 2001.
6) Gould, J., Golob, T. and Barwise, P.: Why Do People Drive To Shop? Future Travel and Telecommunications Trade-offs, Presented at the 77th Annual Meeting The Transportation Research Board Annual Meeting, National Research Council, Washington, DC, January, 1998.
7) Hamer, R., Kroes, E. and Van Ooststroom, H.: Teleworking in Netherlands: an evaluation of changes in travel behavior. Transportation, 18, pp. 365-382, 1991.
8) Ishikawa, H.: and Nishimura K. Impact and preliminary results of telecommunications deregulation in Japan. IEEE Communications Magazine, July, pp. 100-104, 1998.
9) Mitomo, H. and Jitsuzumi, T.: Impact of telecommuting on mass transit congestion: the case of Tokyo. Telecommunications Policy, 23, pp. 741-751, 1999.
10) Mokhtarian, P.: An empirical evaluation of the travel impacts of teleconferencing, Transportation Research A, 22, pp. 283-289, 1988.
11) Mokhtarian, P.: A typology of relationships between telecommunications and transportation, Transportation Research A, 24, pp. 231-242, 1990.
12) Mokhtarian, P.L. and Meenakshisundaram, R.: Beyond tele-substitution: disaggregate longitudinal structural equations of communications effects, Transportation Research C, 7, pp. 33-52, 1999.
13) Mokhtarian, P.L.: A conceptual analysis of the transportation impacts of B2C e-commerce, Transportation, 31, pp. 257–284, 2004.
14) Nemoto, J. and Asai, S.: Scale economies, technical change and productivity growth in Japanese local telecommunications services, Japan and The World Economy, 14, pp. 305-320, 2002.
15) Nilles J. M.: Telecommunications and organizational decentralization, IEEE Transactions On Communications, 23: pp. 1142–1147, 1975.
16) Nilles, J. M., Carlson F.R. Jr., Gray, P. and Hanneman, G. J.: The Telecommunications and Transportation Tradeoff: Options for Tomorrow. New York: John Wiley & Sons, 1976.
17) Nilles, J. M.: Traffic reduction by telecommuting, Transportation Research A, 22, pp. 301-317, 1988.
18) Pool, I. De Sola: (ed.) The Social Impact of The Telephone, Boston: MIT Press, 1977a.
19) Pool, I. De Sola: The Communication/transportation tradeoff. In: In: Pool, I. De Sola (ed.) (1977) The Social Impact of The Telephone, Boston: MIT Press, 1977b
20) Pool, I. De Sola: Communications Without Boundaries, Cambridge, MA: MIT Press, 1980.
21) Pool, I. De Sola: (1982) Communications technology and land use. In: L.S. Bourne (ed.). Internal Structure of The City, Oxford: Oxford University, pp. 450-458, 1982.
22) Pool, I. De Sola: Forecasting The Telephone: A Retrospective Technology Assessment, Norwood, N. J.: ABLEX Publications, 1983.
23) Salomon, I.: Man and his transport behavior: part 1a. telecommuting-promises and reality. Transport Reviews, 4, pp. 103-113, 1984.
24) Salomon, I.: Telecommunications and travel-substitution or modified mobility?, Journal of Transport Economics and Policy, 19, pp. 219-235, 1985.
25) Salomon, I.: Telecommunications and travel relationships: a review. Transportation Research A, 20, 223-238, 1986.
26) Salomon, I. and Koppelman, F.: A framework for studying teleshopping versus store shopping, Transportation Research A, 22, pp. 247-255, 1988.
27) Senbil, M. and Kitamura, R.: The use of telecommunications devices and individual activities relationships, in CD-ROM of Proceedings of Transportation Research Board's 82nd Annual Meeting, Washington D.C., 2003a.
28) Senbil, M. and Kitamura, R. Simultaneous relationships between travel and telecommunications, The Proceedings of 10th International Conference on Travel Behavior, Lucerne, Switzerland, conference organized by the International Association of Travel Behavior Research (IATBR), 2003b.
29) Shy, O.: The Economics of Network Industries. New York: Cambridge University Press, 2001.
30) Vogelsang, I.: The German telecommunications reform-where did it come from? Where is it? And where is it going? Perspektiven der Wirtschaftspolitik, 4 (3), pp. 313–340, 2003
31) Visser, E-J. and Lanzerdorf, M.: Mobility and accessibility effects of b2c e-commerce: a literature review. Tijdschrift voor Economische en Sociale Geografie, 95, pp. 189–205, 2004.
32) Wiegman, B.W., Beekman, N., Boschker, A., Van Dam, W., and Nijhof, N.: ICT and sustainable mobility, Growth and Change, 34, pp. 473-489, 2003.