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A TYPOLOGY OF RELATIONSHIPS BETWEEN TELECOMMUNICATIONS AND TRANSPORTATION

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Abstract—This paper defines the relationship between telecommunications and transportation, by expanding on linkages already identified in the literature, by identifying additional relationships, and by putting these relationships into a robust conceptual framework. There are conceptual, physical, analytical, and regulatory parallels between telecommunications and transportation. Telecommunications affects the demand for, and supply of, transportation—and vice versa. In the broadest sense, all communication requires transportation in order to occur: transportation either of people, of objects, or of electronic impulses. In other words, communication takes place via one or more of those three modes. It is suggested that "communication breeds communication." That is, the easier it is to communicate (whether through travel or telecommunications), or the more that one or another form of communication takes place, the more that communication as a whole is stimulated. The relative shares of each of the three modes of communication may vary as one mode partially substitutes for another, but the absolute amounts of communication via each mode are likely to increase. Two empirical studies are summarized, one illustrating that teleconferencing increased travel, the other illustrating that telecommuting decreased travel. Other implications for transportation planning are highlighted.

1. INTRODUCTION

The relationship between telecommunications and transportation has been discussed in the transportation literature (and that of the related disciplines of energy and air quality) for at least 25 years (see, e.g., Harkness, 1977; JALA Associates, 1983; Jones, 1973; Khan, 1976; Kraemer, 1982; Kraemer and King, 1982; Lathey, 1975; Memmott, 1963; Nilles *et al.*, 1976; and Obermann *et al.*, 1978). The energy crisis of the early 1970s prompted much of the initial research into the substitutability of telecommunications for travel. As the publicly perceived urgency of the energy crisis waned somewhat in the early 1980s, so too did research into energy conservation measures including telecommunications substitutions.

The mid-to-late 1980s, however, have seen a resurgence of interest, among transportation planning academicians and especially practitioners, in the potential impacts of telecommunications on their field. Because of the persistent attractiveness of reducing travel, whether to save energy, decrease congestion, or improve air quality, it is not surprising that most of the relevant literature on the transportation demand side has concentrated on the substitution potential of telecommunications for travel. However, other relationships between the two fields have not escaped notice, and indeed the roots of those relationships date back much further than 25 years, as will be discussed later. The literature (Salomon, 1986; ECMT, 1983) identifies four different kinds of relationships: (i) substitution (e.g., telecommunications decreases travel); (ii) enhancement (e.g., telecommunications directly stimulates travel); (iii) operational efficiency (e.g., telecommunications improves travel by making the transportation system more efficient); and (iv) indirect, long-term impacts (e.g., telecommunications may ultimately affect land use, which will affect travel). Salomon refers to (iii) as first-order complementarity and to (ii) as second-order complementarity.

All these relationships refer to the impact of telecommunications on transportation. However, the converse set of relationships—that is, the impacts of transportation on telecommunications—are also important. The purpose of this paper is to define the relationship between telecommunications and transportation, by expanding on the linkages already identified, by identifying additional relationships, and by putting these relationships into a robust conceptual framework. This will lead to a broader, more complete understanding of the potential impacts of telecommunications on transportation—*and* vice versa.

The following section discusses certain parallels between telecommunications and transportation. Section 3 recasts the four relationships listed above into the familiar economic framework of supply and demand, and presents examples of supply-demand relationships between the two areas. Section 4 elaborates on the conceptual framework linking communications and transportation. Section 5 describes the findings of two empirical studies of the impact of telecommunications on the demand for travel. The concluding section summarizes some implications for the transportation planning profession.

2. PARALLELS BETWEEN TELECOMMUNICATIONS AND TRANSPORTATION

There are a number of interesting parallels between telecommunications and transportation. First, there are conceptual parallels. These are discussed at greater length in Section 4; some brief observations are made here. Telecommunications may be thought of as the transportation of information. In the telecommunications trade literature, it is quite common to come across phrases like, "telecommunications highway," "information pipeline," "voice and data traffic." "Teleports" are to information transportation what "airports" and "seaports" are to passenger and freight transportation. Even the word "bus," to stretch the point, has specialized meaning in local area network (LAN) architecture, as does the word "bridge" for audioconferencing.

Conversely, it is axiomatic that transportation is a derived demand. The demand for freight travel derives from the spatially dispersed demand for goods. Passenger travel is undertaken not for its own sake (by and large), but to participate in an activity at the trip destination. Often the main purpose of transporting those goods or participating in that activity is to communicate something. Thus, communication outside the direct range of our senses cannot take place without transporting something—either a person, a physical object such as a letter or photograph, or electrons or radio waves.

There are physical parallels between telecommunications and transportation: telecommunications networks are often superimposed on existing transportation networks. These physical parallels are at least a century-and-a-half old: the first uses of the telegraph included facilitating the operation of rail systems, and consequently early telegraph networks often followed railroad rights of way (see, e.g., Kieve, 1973; Harlow, 1936). Today, local telephone systems and cable television delivery systems normally follow city streets and roads. The relationship between the transportation and the telecommunications entity in these cases is primarily that of regulator to regulated; access to the public rights of way is typically regulated under a state or local franchise.

In recent years, other financial *partnerships* (as opposed to largely regulatory relationships) have arisen between telecommunications service providers and transportation entities, typically giving the telecommunications provider the right to lay fiber optic cable for regional or long-distance communications in the transportation right of way. This partnership may simply be a lessor-lessee relationship (perhaps in which the lessor, the transportation agency or company, is also granted some capacity on the telecommunications network for its own communications purposes), a joint venture between the two parties, or full-fledged ownership of one by the other. The following examples serve partially to illustrate the range of existing financial partnerships involving co-location of networks:

(i) Perhaps the most well-known modern example of this physical parallel is U.S. Sprint, which was originally owned by Southern Pacific Railroad and initially followed SP rights of way.
(ii) Lightnet is a five-year-old joint venture between Southern New England Telephone and the CSX railroad holding company. Its chief asset is an all-fiber network strung largely along CSX rights-of-way. Based in Rockville, Maryland, Lightnet handled $100 million of long-distance business in 1987.
(iii) The Williams Telecommunications Group (now a member of the National Telecommunications Network consortium) began by using abandoned gas pipelines throughout the Midwest as conduit for fiber-optic cables (Keppel, 1988).
(iv) The Washington (DC) Metropolitan Area Transit Authority (WMATA) has authorized a regional telecommunications carrier, Institutional Communications Company, to install fiber optic cable throughout its subway system. In return, WMATA receives a portion of network capacity to use for its own telecommunications needs (Killette, 1987).

There are analytical parallels between telecommunications and transportation. By nature, both fields involve networks. Each type of network can have links of different capacities, can permit different speeds of travel, can be designed for different kinds of traffic. In transportation, for example, link capacities range from that of say, a two-lane country road to that of a 12-lane urban freeway; in telecommunications, capacities range from that of the twisted copper pair of Plain Old Telephone Service, to those of "broadband" media such as satellites or fiber-optic cable. The concept of "impedance" has been transferred from electrical networks to transportation networks.

Since in many key respects "a network is a network," several classes of analytical techniques can apply as well to telecommunications as to transportation networks. Queuing theory is an obvious example, which has been used to model the behavior of cars on streets and the utilization of other transportation service facilities as well as the distribution of telephone calls and the sizing of telecommunications facilities (see, e.g., Giffin, 1978). Mathematical programming techniques (such as network optimization and integer programming) have also been applied in both fields (Ford and Fulkerson, 1962).

Finally, there are regulatory parallels between telecommunications and transportation. Historically, segments of each industry have been considered natural monopolies, although as Kahn (1971, pp. 2, 10) and others point out, this designation is open to debate in general, and even if it is granted for one point in time, it may not hold at a later point due to technological advances. Certain kinds of service providers in each industry are considered "common carriers," and therefore in some respects have been regulated similarly. (There is, however, at least one important regulatory *difference* between transportation and telecommunications common carriers. The Reed-Bulwinkle Act of 1948 conferred immunity from anti-trust regulation on transportation carriers [see Chapters 20 and 22 of Sampson *et al.*, 1985], while the telecommunications industry enjoyed no such protection. The anti-trust suit launched in 1974 by the Justice Department against AT&T that led to the divestiture of the Bell Operating Companies in 1984 was only the latest in a series of antitrust actions targeting AT&T throughout its existence—see, e.g., Brock, 1981.)

In the United States, regulatory jurisdiction for telecommunications and transportation carriers often falls under the same governmental body, such as a Public Service Commission or Public Utilities Commission in many state administrations. At the local level, until the creation of a new Department of Telecommunications in 1985, cable television franchise administration in the City of Los Angeles resided under the Department of Transportation (DOT). Aside from the physical parallels between the cable television network and city streets referred to above, the rationale was that DOT's lengthy experience in franchising taxi service should be largely transferable to franchising cable television service.

Segments of both telecommunications and transportation industries are undergoing extensive *de*regulation, as well. Rate of return as the basis for price regulation has been weakened or eliminated for various segments of the transportation industry (see Chapter 22 of Sampson *et al.*, 1985, for a general discussion), and is now apparently undergoing similar erosion in the telephone industry (see, e.g., Mason, 1989a, 1989b).

There are certainly issues arising out of deregulation that are common to both industries. One such issue is "cream-skimming," referred to in the telecommunications industry as "bypass." In a regulated public utility with an expressed or implied mandate for "universal service," the provider typically subsidizes the cost of providing service to uneconomical market segments by charging some people more than their fair share of the costs would indicate. In a deregulated business, a competitor can identify a segment of the market for which it is profitable to offer comparable service at a lower price. As customers migrate to the competitor, revenues to the initial provider may be reduced to the point that it can no longer support the uneconomical segment of the market. Hence, deregulated airlines cancel unprofitable routes, and Bell Operating Companies cry that their point-to-point competition will erode their subscriber base to the point of jeopardizing universal service. Somewhat similar principles are involved in the debate over whether/when public mass transit should be privatized.

The regulatory parallels have not escaped popular notice. A *Los Angeles Times* article analyzing the success of niche telecommunications marketing states,

> [Regional telecommunications carriers] are, in some ways, analogous to the small airlines that developed after deregulation of that industry to serve markets abandoned by larger carriers. Just as these small airlines haul passengers to major airports where they can catch planes to their final destinations, the small long-distance companies carry their customers' calls to a metropolitan area where they are switched onto the network of another company . . . (Keppel, 1988)

3. SUPPLY-DEMAND RELATIONSHIPS BETWEEN TELECOMMUNICATIONS AND TRANSPORTATION

The conceptual and physical parallels discussed above suggest another perspective from which to view telecommunications/transportation relationships: the economic perspective of supply and demand. That is, telecommunications affects the demand for, and supply of, transportation—and vice versa. The following subsections provide some specific examples of the impacts of transportation on telecommunications demand and supply, and the impacts of telecommunications on transportation demand and supply. The latter set of impacts is naturally of most direct interest to the transportation profession. However, it is also important to be aware of the implications of the transportation environment for the telecommunications industry, especially in view of the feedback relationships discussed below.

3.1 The impact of transportation on the demand for telecommunications

A number of telecommunications products and services are directly targeted to segments of the transportation industry; hence, transportation may be said to stimulate the demand for those products and services. Obvious examples include nearly all forms of mobile communications—that is, those forms which are vehicle-based (as some future mobile communications devices become more person-based, along the lines of Dick Tracy's two-way wrist radio, the link to transportation, at least motorized transportation, will become more tenuous).

These products and services may be operations-related, largely arising from the need for information on, and control of, the movement of passengers and cargo. These include: navigational devices; tracking/location equipment; dispatch services; and ship-to-shore and ground-to-air capabilities. A historical example is again the development of the telegraph, which was partly fueled by the need for "real time," reliable communication on the status of trains.

Or these products and services may be related to personal communications, such as: Airfone and Railfone services, permitting plane or train passengers to make phone calls in transit; and cellular radio, or car phones.

Despite the apparently symbiotic relationship between telecommunications and transportation entities, their interests do not always coincide. To illustrate the potential difference in perspective between telecommunications and transportation service providers, consider the impact of commute congestion on car phone demand. The longer people are stuck in traffic, the more they are likely to use their car phones. What is a major crisis to the transportation planner is a major windfall to the mobile telephone service provider. It is probably no coincidence that gridlocked Los Angeles is heralded as the largest cellular radio market in the world (Kim, 1987), although other factors besides congestion (such as occupation and income) certainly come into play in affecting the demand for car phones.

3.2 The impact of transportation on the supply of telecommunications

Some examples of this relationship have been referred to in Section 2, in the use of transportation rights of way to construct fiber optic (and other) networks. It can be safely concluded that at least some start-up long-distance phone companies probably would not be able to exist independently of a transportation partner to provide a ready-made right of way, although there are notable counterexamples such as MCI. Another example is the impact of space transportation on the supply of satellite communications capacity.

3.3 The impact of telecommunications on the demand for transportation

A great deal has been written on this relationship, particularly on the substitutionary potential of telecommunications for travel. A list of some currently practiced substitution applications includes the following.

(i) *Telecommuting:* working at home or other remote location, with telecommunications links to a central office.

(ii) *Teleconferencing:* meeting at multiple locations, with audio, video, and/or data links among sites.

(iii) *Teleshopping:* using computer- or television-based services to obtain information about, and sometimes to purchase, products (see Salomon and Koppelman, 1988). Telemarketing, both in-bound (a customer calling an "800" number to place an order, typically prompted by a mail or television advertisement) and out-bound (the systematic telephoning of a target market to solicit orders for a product or service), may be considered a form of teleshopping. Teleshopping may not substitute for a shopping trip *per se*. It often either replaces a mail-order catalog choice or represents an impulse purchase, or both. Nevertheless, as videotex services become more common, an increasing number of shopping trips will be replaced.

(iv) *Telebanking:* using a computer with modem and/or a touch-tone telephone to perform banking transactions such as paying bills and transferring money between accounts. Automated teller machines (ATMs) may also be considered a form of telebanking, especially to the extent they are found in convenient places not requiring a separate trip to access.

(v) *Tele-entertainment:* the use of telecommunications to transmit a cultural, athletic, or other entertainment activity to multiple locations. Televised live events qualify as tele-entertainment, as do cable TV movies. The lowly radio also fits this category. Videocassettes are an interesting hybrid. They do not involve long-distance transmission and so may only loosely be considered "tele"-entertainment, but their effect of diffusing the viewing audience into numerous small entities rather than one large one is comparable to that of TV movies (whether broadcast or cable). On the other hand, unlike TV movies, videocassettes typically require a trip to purchase or rent them, suggesting that their transportation impacts may be closer to those of in-theater movies than to broadcast or cable programming. Those impacts will by no means be identical, however: a trip to acquire a videotape is likely to be quite different in time, pattern (i.e., the kinds of other activities, if any, linked to the trip), and possibly space than a trip to the movies. This example serves to point up the complexity of the interactions between communications and transportation.

Several special cases of teleconferencing deserve individual mention:

(vi) *Tele-education:* Distance learning, as it is sometimes called, involves using satellite, microwave, or cable television systems to transmit classroom instruction to one or more remote locations. This telecommunications application is quite common; industry experts believe that around 80% of all teleconferencing is for education or training purposes (Portway, 1988). Tele-education is being used to: transmit entire degree programs from accredited universities to worksites; share specialized teachers among multiple grade schools in a metropolitan area; transmit advanced placement courses from college campuses to high school campuses; provide instruction at home; and reach into rural areas.

(vii) *Tele-medicine:* Improbable as it may appear at first glance, some medicine can effectively be practiced remotely. Video and data links make it possible for health professionals in rural parts of the country to transmit video images, X-rays, and other information to a specialist in a metropolitan area, and receive an intelligent diagnosis and treatment regimen without a lengthy (and in some cases medically dangerous) trip for the patient (*The Futurist*, February 1985). Conversely, the same operation that can be seen in-hospital via closed-circuit television can be transmitted to any number of outside sites for maximum teaching effectiveness.

(viii) *Tele-justice:* Routine functions such as depositions and arraignments can now be handled through videoconferencing or even audioconferencing links between the courthouse and the prison. This capability eliminates the costs and hazards of transporting prisoners back and forth without compromising due process. The years 1988 and 1989 saw perhaps the first case of international tele-justice, in which two British residents served as witnesses in a U.S. trial through a videoconferencing arrangement between a London hotel and the Milwaukee courtroom (*Communications News*, February 1989).

The above applications deal primarily with the replacement of passenger transportation by telecommunications. Freight transportation can also be substituted for by telecommunications, however. Electronic data transmission using modems can substitute for physical shipment of information products. Satellite transmission of newspapers such as the *Wall Street Journal* and *USA Today* to widely dispersed printing plants substitutes for centralized shipping and delivery networks. Many documents now transmitted by facsimile would a few years ago have been sent by overnight or conventional mail, although there is also evidence that fax has pilfered market share from another telecommunications service: electronic mail (Thomas, 1989).

Despite the seemingly extensive list of trip substitution applications, telecommunications can also serve to stimulate travel, as indicated in the Introduction. Mokhtarian (1988) and others point out that this stimulation effect can arise in several ways:

(i) *Short-term direct:* Telecommunications can make information about people and activities much more accessible than would otherwise be possible. This information may create the desire to travel to participate in those activities and interact with those people. Further, as the obverse of the point that transportation stimulates the demand for mobile telecommunications, the ability to communicate while traveling may itself stimulate more travel, or at least inhibit attempts of transportation planners to reduce travel. The availability of a car phone, for example, may discourage a commuter from adopting vehicle trip reduction strategies such as transit or ridesharing. One enterprising transportation provider in Los Angeles jumped into this marketplace vacuum with luxury shuttle vans equipped with cellular phones, VCRs, and faxes (Bush, 1988), but the economic viability of such a service remains unproven. This particular service was terminated a few months after opening (Wolf, 1989).

On the other hand, the availability of kiosks with real-time route and schedule information might stimulate transit usage. And proposed videotex systems for promoting ad hoc carpool formation (Ferrell, 1984; Hawaii Department of Planning and Economic Development, 1984) might increase both ridesharing demand and supply.

(ii) *Short-term indirect:* The time saved by telecommunications substitution for travel may be used to make other trips. Thus, for example, companies with in-house videoconferencing facilities often do not find a reduction in travel costs, as teleconferenced meetings are supplemented by other (perhaps more desirable or more essential) trips.

(iii) *Long-term:* Telecommunications infrastructure and services may lead to long-term changes in land-use patterns (e.g., more dispersed residential and employment locations) that may in turn result in longer trips or more travel in general.

The substitutionary and complementary aspects of the relationship between transportation and telecommunications will be discussed more generally in Section 4.

3.4 The impact of telecommunications on the supply of transportation

Telecommunications can increase the effective level of service of a transportation system by supporting more efficient use of existing networks. This is by no means a development confined to recent advances in telecommunications technology: Beniger (1986) traces the roots of the so-called "Information Revolution" to a "crisis of control" in the production, distribution, and consumption of goods and services in the middle of the last century. Examples of telecommunications-based control or feedback systems supporting goods and people movement include: (i) highway emergency call boxes, permitting quicker removal of accidents; (ii) changeable message signs to route traffic around major incidents; (iii) real-time traffic signal synchronization and priority override; (iv) CB radios, permitting prompt accident reporting and route diversion; (v) freeway ramp metering; (vi) remote video surveillance of freeway ramps and high-occupancy vehicle lanes, permitting more effective enforcement and incident management abilities; (vii) in-vehicle navigation devices; (viii) automated vehicle and guideway technologies; (ix) radio determination satellite systems (RDSS), permitting tracking and control of cargo at any point in the shipment (Dow, 1989); (x) electronic document transfer among shippers, customers, and Customs officials (Feldman, 1986); (xi) voice mail systems for truckers, reducing the difficulty of communication between dispatchers and drivers on the road; and (xii) microwave landing systems for aircraft, which the Federal Aviation Administration has suggested can provide up to 50% more capacity at congested airports than conventional instrument landing systems (*Airport Highlights*, 1989).

A number of these elements (including, at least, ii, iii, v and vii) are being combined in the three-year, $1.6 million, "Smart Corridor Telecommunications Demonstration Project," for the Santa Monica Freeway Corridor in Los Angeles. Also known as the Pathfinder Project, it is authorized by State Assembly Bill 1239, and funded by FHWA, Caltrans, and General Motors (Gherardi, 1989). The project will test whether the integration of these and other strategies significantly decreases congestion in that corridor. The six-year, $56 million, Program on Advanced Technology for the Highway (PATH), conducted by the University of California, is exploring a number of elements relating to automated vehicles and roadways (*TR News*, July–August 1989, p. 19; Kanafani and Parsons, 1989). Similar studies are already well underway in Europe, under the seven-year, $1 billion Promotheus project (Beck *et al.*, 1988).

It is no accident that some applications appear here as well as in the list of examples of ways that transportation affects the demand for telecommunications. There is a feedback mechanism at work among a number of these relationships. For example, transportation generates the demand for transportation-oriented telecommunications products and services, and those products and services in turn affect supply of and demand for transportation.

The relationships discussed in this section may be summarized by the diagram in Figure 1. The vertical arrows represent traditional supply/demand relationships for a single category of "goods." The horizontal arrows represent the cross-category relationships described above. The absence of crossover arrows between, for example, transportation demand and telecommunications supply, is not meant to suggest that those relationships do not exist, but rather that they tend to be indirect: for example, transportation demand affects telecommunications demand which in turn affects telecommunications supply.

The relationship between transportation demand and telecommunications demand goes beyond transportation giving rise to niche telecommunications products, or telecommunications products making it more attractive to travel. Transportation also generates niche food products such as airline meals, but the telecommunications/transportation interaction is more intimate than that. In many cases, transportation can accomplish the same purpose as telecommunications—they are conceptually two facets of the same idea. Thus, they can either be competing modes of communication (substitutes), or they can synergistically support each other in increasing all forms of communications (complements). This relationship is explored more fully in Section 4.

4. THE CONCEPTUAL RELATIONSHIP BETWEEN TELECOMMUNICATIONS AND TRANSPORTATION

Some conceptual parallels between telecommunications and transportation were briefly advanced in the preceding sections. It is useful to expand the discussion slightly, to explore the relationships among communications, telecommunications, and transportation.

In the very broadest sense, all communications require transportation in order to occur. That transportation may take one or more of three forms: (i) transportation of people, to meet face-to-face (or within earshot); (ii) transportation of objects, such as letters, books, newspapers, audio- or videotapes, floppy disks, and so on; and/or (iii) transportation of electronic impulses, either in the form of electrical current along copper wires, coaxial cable, or optical fiber, or in the form of radio waves through the air.

The situation is not symmetric, however. The role of transportation in all forms of communication is that of a *sine qua non*: the transportation, in effect, constitutes the act of communication. On the other hand, the role of communications in some forms of transportation is ancillary or even nonexistent. Even if it is a necessary adjunct to the transportation, it does not itself constitute that transportation. In the case of transporting people, leisure travel does not have communication as its primary purpose, although some communication will almost inevitably be associated with it. Most freight transportation has the delivery of goods rather than information as its primary aim, the exceptions being the kinds of information freight identified in (ii) above. And electronic impulses such as electromagnetic radiation do not always include meaningful information. Microwaves, for example, can either transmit data or cook food.

If transportation and telecommunications are simply alternate forms of communication, then their relationship to each other (i.e., whether substitutes or complements) is affected by what is happening to communication in general. It has been hypothesized (e.g., Salomon, 1986) that communication is increasing exponentially. This suggests that "communication breeds communication." That is, the easier it is to communicate (whether through travel or telecommunications), or the more that one or another form of communication takes place, the more that communication as a whole is stimulated. This implies that increases in travel will generally lead to increases in the combination of personal travel, telecommunications, *and* transportation of information products, and that increases in telecommunications will also generally lead to increases in the combination of the same three areas. The relative shares of each of the three modes of communication may vary as one mode partially substitutes for another, but the absolute amounts of communication via each mode are likely to increase. Figure 2 illustrates this principle of potentially simultaneous substitution and generation: in the example shown, the actual amount of personal travel increases as part of a general expansion in communication, even though its share as a communication mode declines. It is the combination of these two counteracting forces that makes it so difficult to determine the net impact of telecommunications on transportation (or conversely) in any particular context.

The following historical, anecdotal, abstract, and hypothetical examples of this principle serve to illustrate the range of possibilities:

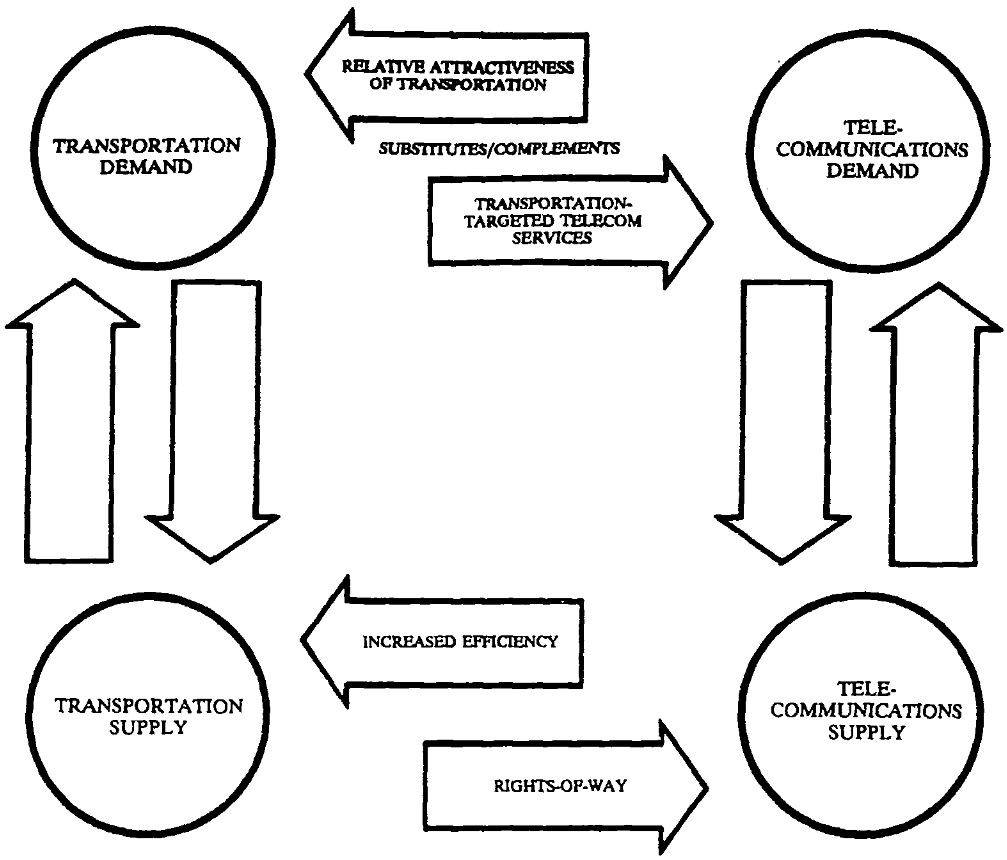

Fig. 1. Supply-demand relationships between telecommunications and transportation.

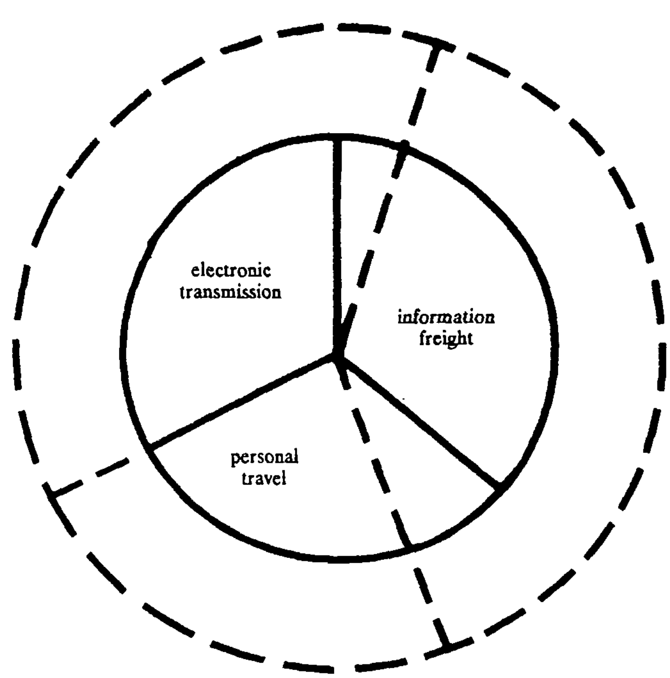

Fig. 2. Relative substitution among communications modes, simultaneous with absolute expansion of all modes.

(i) In the 1960s, a prototypical videotelephone system was installed between two New Jersey Bell Laboratories locations about 100 miles apart. Before the videophone, a researcher at location A would call a colleague at location B to discuss the latest brainstorm. "That's interesting," the colleague would say. "The next time I'm over there I'll drop by and we can discuss it some more." After the installation of the video link, the researcher would call the colleague and say, "Look what I'm doing." "Amazing!" the colleague would reply. "I'll be right over!" Use of the company car fleet for inter-site travel increased appreciably following the introduction of the videophone (Ross, 1987).

(ii) It is rather profound that the first words spoken by Alexander Graham Bell into the telephone he had just invented were, "Watson, come here, I want you" (de Sola Pool, 1977, p. 12). Even though the trip was just a few feet down the hall in this case, the very first use of that most universal telecommunications product, the telephone, was to generate a trip for the purpose of face-to-face communications.

(iii) While the impact of facsimile machines on overnight package delivery services has been palpable (Clarkin, 1988), analysts speak in terms of slowed growth rates for the delivery companies, not loss of business in absolute terms. Again, the expansion of the total market more than compensates for relatively small changes in market share.

(iv) The congestion, energy, and air quality benefits of new urban freeways are under debate (see, e.g., Newman and Kenworthy, 1988; Newman, *et al.*, 1988; and Plane, 1986, pp. 389–90). On the one hand, *ceteris paribus*, increasing capacity will reduce congestion, which will improve air quality and decrease fuel consumption. But new freeways do not keep all other things equal. They induce new demand (the argument goes) by making travel in that corridor comparatively very attractive – that is, until the new freeway fills up (which is often the day it opens), all the old freeways fill back up, and overall congestion is at least as bad, only at higher levels of demand. It is also argued that new freeways promote more dispersed (therefore less energy-efficient) land-use patterns and discourage the use of mass transit.

(v) Along the same lines, the availability of telecommunications services will promote more telecommunications. Consider the examples of potential trip substitution applications listed in the previous section. In many cases they may not be fulfilling existing communications demand through telecommunications instead of travel, but creating new demand that will be fulfilled through telecommunications or not at all. Impulse teleshopping is one example. In the case of tele-education, many participants would not be taking the class at all if it were only offered on campus. Much of tele-entertainment (e.g., a televised concert, play, or sports event) would have to be considered new entertainment opportunities for the largest part of the viewing/listening audience rather than alternative ways of participating in existing opportunities. And it has been found that teleconferencing may lead to more meetings, and more people at a given meeting, than would be the case otherwise (Green and Hansell, 1984).

(vi) Even while telecommunications stimulates the demand for more telecommunications, it may increase travel as well. As indicated in the previous section, this may be a short-term effect either direct or indirect in nature, or a long-term effect related to changes in land use.

(vii) Companies (such as Federal Express, Texas Instruments, and Apple Computer) with extensive in-house satellite videoconferencing networks report an unexpected stimulation effect on the demand for business-related videotapes. For example, the Texas Instruments sales force wanted copies of a press conference held by satellite, so that it could provide the information to customers. This led to the creation and distribution of 5,000 videotapes. "This wouldn't have happened before we had our satellite network," a TI spokesman stated. "Our demand for tape is increasing by an order of magnitude." Echoes Federal Express, "Seeing programs by satellite seems to increase the demand for programming overall" (Amato, 1989).

(viii) Assessments of the impacts of new communications technologies on the old are often, in retrospect, laughably off the mark. The "paperless office" was widely heralded a few years back, as a probable consequence of the introduction of personal computers into the workplace. Instead, there has been a paper explosion, with no slowing down in sight. Similarly, doomsayers predicted the demise of radio and newspapers with the introduction of television, whereas in fact the old forms of communication are flourishing comfortably beside the new. On the other hand, there was early concern that the telegraph would compete "too" effectively with the postal service (Harlow, 1936). Instead, of course, the mail has survived while the telegraph has been eclipsed by later technology. Obviously, some forms of transportation (horses, clipper ships) and telecommunications (telegraph) have and will become obsolete or reduced to hobbyist proportions (the futurist Paul Saffo recently suggested that the same thing may happen to books as we know them – Koenenn, 1989), but the record of predicting such changes is mixed at best.

It is perhaps human nature to think of innovations in terms of how they can help us do old things differently. Soon, however, it becomes apparent that they also help us do new things. Thus, automobiles started out as "horseless carriages," and telephones were originally thought of as good substitutes for messenger boys (ECMT, 1983). Indeed they were, and a good deal more besides!

The point is that it is dangerous to count on the substitution of telecommunications for transportation in any but a relative sense. The substitution potential is genuine, of course. As the ECMT (1983, p. 79) report puts it, "the simple *reductio ad absurdum*—what would our roads be with no telephone?—is sufficient proof if proof were needed." Nevertheless, that same example also illustrates the synergistic effect of telecommunications and transportation: had the telephone not been invented, the entire economy would be drastically different than it is today, and much of the transportation we are asked to envision would simply never have been generated.

5. EMPIRICAL EXAMPLES OF THE TELECOMMUNICATIONS/TRANSPORTATION DEMAND RELATIONSHIP

Two recent empirical studies illustrate some of the aspects of the relationship between the demand for travel and the demand for telecommunications that have been discussed above. In the first, telecommunications may be said to have stimulated travel, while in the second, telecommunications clearly reduced travel—at least in the short term. Together, they point up the difficulty of predicting even the direction, let alone the magnitude, of the impact of telecommunications on travel demand in any specific instance. Both studies were performed by the author while an employee of the Southern California Association of Governments (SCAG), the metropolitan planning organization covering six counties in Southern California.

5.1 SCAG videoconference

In February of 1986, the regular monthly meeting of SCAG's Transportation and Communications Committee (TCC) was held as a two-way videoconference between two California State University campuses, instead of at the usual single location in SCAG offices. Details of the videoconference and its evaluation are reported elsewhere (Mokhtarian, 1988; SCAG, 1986b). The key findings were that: (i) the average trip length per person was 24% *less* for the videoconference than for a meeting at SCAG; but (ii) total vehicle-miles traveled were 29% *higher* for the videoconference than for a typical TCC meeting held at SCAG. That was because (iii) attendance at the videoconference was *64% higher* than average.

The evaluation dealt with the question of whether the higher-than-average attendance would have occurred if the same meeting had been held in the conventional fashion, or whether it could be attributed to the teleconference, and inferred that the latter was by far the more likely explanation. Whether due to a novelty effect, or because the meeting actually fulfilled its objective of being more convenient for more people, or (most probably) some of both, telecommunications increased travel.

The study concluded that the observed increase in travel should not necessarily be a cause for despair. In the first place, the benefit of achieving improved communication can be viewed as outweighing the disadvantage of creating additional travel. In the second place, even the additional travel that took place was not as troublesome as it might seem. Because of the teleconference, the travel was redistributed in time and space to less congested parts of the transportation system. It is possible that the net impact on *congestion* was negligible or even positive.

5.2 SCAG telecommuting pilot

It has been speculated that new travel generated by telecommuting could largely obviate the benefits of the commute travel saved. Salomon (1985) suggests that the synergistic effects of multiple telecommunications applications in the home might lead to increases in travel, whether simply due to the "cabin fever" of being cooped up in the home all day, or due to the attempt to fulfill more complex psychosocial needs. It may be argued that this likelihood will be much stronger in a work-at-home (especially full-time work-at-home) situation than for local work centers. In an admittedly short-term, small-sample test conducted at SCAG, the hypothesis of significant travel generation was not supported, even for working at home.

From June to November 1986, SCAG conducted a telecommuting pilot project for its employees (SCAG, 1986a). Seventeen people worked at home and one person worked at a satellite location, about one full day every one-and-a-half weeks on average. Among other things, the transportation impacts of telecommuting were evaluated. The major findings were as follows (SCAG, 1988).

(i) Telecommuting saved an average of 46 miles per occasion (that is, per person-day of remote work).
(ii) Not even half (45%) of all telecommute occasions generated travel during the usual commute and work hours.
(iii) About five miles per occasion were generated.
(iv) Of that five miles, only about 0.2 miles were attributed to new trips that would not have taken place anyway, and some of that travel involved walking trips.
(v) The remaining 4.8 miles generated per telecommute occasion were attributed to activities that would have taken place (at the same destination) even if the conventional commute had been made. Assuming those activities would have been linked to the work trip, the amount of new travel they represent depends on the extent to which those activities fall on the route to work. An activity which is precisely on the way

to work generates 100% new travel in a telecommuting situation, because that activity could have taken place at no marginal cost if it had been linked to the work trip. On the other hand, an activity which is essentially out of the way generates no *new* travel, because virtually the same amount of travel would have been generated to conduct that activity in conjunction with the work trip.

(vi) Thus, there was a net savings of more than 41 miles per telecommute occasion.

(vii) As with the SCAG teleconference, even the extra miles that were generated entirely due to telecommuting were redistributed in time and space to less congested parts of the transportation system.

Again, these findings are far from definitive. A much larger pilot project now underway involving employees of the State of California (see JALA Associates, 1985; Kitamura, *et al.*, 1990) will provide more extensive data on the issue. But the SCAG results are plausible, and consistent with previous findings (Nilles, 1988). A telecommuter who is truly working eight hours a day won't have a lot of time to make extra trips. A newly available car may be used by another household member, but those trips would probably tend to be far shorter than the average commute and to take place in the off-peak.

6. CONCLUSIONS

Throughout this discussion, a number of points of interest to the transportation planning profession have emerged. These points are summarized below:

(i) There are strong commonalities between telecommunications and transportation. These linkages are first and foremost conceptual, but also physical, analytical, regulatory, and economic.

(ii) The partnerships between the two fields can have mutually beneficial impacts on both supply and demand, as when transportation providers lease rights of way to telecommunications providers, or when telecommunications technology is used to make traffic flow more smoothly, or when telecommunications reduces the demand for some kinds of travel.

(iii) Despite the close ties between the two fields, however, there will be situations for which telecommunications providers will have a different agenda than transportation providers. This was seen to be the case for car phones. It is also true to a lesser degree for videoconferencing: the videoconference provider wants to increase the use of transmission time and terminal equipment, oblivious to the additional travel created because attending the meeting becomes easier for more people.

(iv) Technology will create hybrid situations, that defy established categorizations. Thus, the home viewing of commercial videocassettes is like viewing a TV movie as far as its impact on movie theaters is concerned, but (somewhat) like a trip to the movies as far as its transportation impact is concerned.

(v) In general, a synergistic generation effect among the three forms of communication (person transportation, transportation of information objects, and telecommunications) can be expected. That is, the more that one or another form of communications takes place, the more that all forms of communication are stimulated. There are numerous examples of this.

(vi) Advances in communications technology will permit us to do more things and new things, not just the same old things in a different way. It is the inability to imagine those new things that invariably confounds attempts to predict the future as a continuation of the past. On the other hand, the opposite extreme—predicting the demise of old technology in the face of the new—is equally problematic.

(vii) The potential for relative substitution among the three modes is genuine; real-life examples abound. The preliminary findings on telecommuting, for example, are encouraging. Nevertheless, any travel savings that occur may have a very localized impact, and it should be realized that the relative share of, say, transportation may decline even while its absolute level is rising.

(viii) Finally, the most important impact of telecommunications may not be that it increases or decreases the amount of travel that takes place, but that it permits a great deal more flexibility in whether, when, where, and how to travel. Telecommunications loosens the constraint of having to be at a certain place at a certain time. Allowing people to take advantage of the excess capacity in the transportation system at off-peak times and places promotes more efficient use of existing capacity and delays the need to construct expensive new infrastructure.

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