BENEFITS OF SUBSTITUTION OF TRANSPORTATION BY TELECOMMUNICATIONS

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INTRODUCTION

The prosperity of a country depends on having an adequate transportation system. The ability to move people and goods quickly, efficiently, and safety affects not only the economy, but also the quality of life.

The transportation system in most countries is, however, facing a crisis because the demand on the transportation system exceeds supply. Also, the transportation system is a major consumer of our time, user of dwindling energy resources, and creator of a significant burden on the environment. These days, none of these ramifications is acceptable.

These problems are certainly recognized. Both the public and the private sectors are searching for ways to bring about lasting improvements. We can build more roads, subways, and high-speed rail (HSR) lines, and thereby increase the supply side of the transportation equation. We can also wire up our existing vehicles and highways to create an Intelligent Vehicle/Highway System (IVHS). This way we can squeeze more out of what we have. These actions can certainly address the congestion problem and reduce the burden on the existing infrastructure. However, they do not solve the energy or the pollution problems.

There is, however, another way to approach the transportation problems. We can balance supply and demand by reducing the demand on infrastructure, instead of increasing the supply of it. If we reduce the level of transportation activities, we will reduce the demand. Also, reducing the level of transportation activities directly affects the amount of energy used by this sector and the extent of pollution created. Besides, we can additionally make beneficial use of the time freed up in not having to travel.

Telecommunications offers a demand side solution to the transportation problems. The demand on transportation will certainly be reduced if individuals and businesses are provided with the means to work at home, instead of commuting to a place of work; shop at home, instead of having to drive to shops; and conduct business in their offices instead of having to fly or drive long distances. Also, we can substitute transportation of information in paper form by its electronic equivalent. This will result in a further reduction in demand.

The possibility of substituting transportation by telecommunications exists; in fact, it has existed for some time. However, it seems that the attention given to the supply

solutions to the transportation problems exceeds the attention received by the substitution option. In this paper, we have taken the first steps toward correcting this inequality.

This paper provides an objective framework for discussing the societal benefits of substituting transportation by telecommunications. We have identified the substitution opportunities, quantified the impact of substitution, and compared the telecommunications alternative with the other major options being considered in the U.S. to solve the transportation problems. Although this study has focused on the U.S., its methodology is equally applicable to evaluating the benefits of substitution in other countries in the world.

Since this is intended to be more of a discussion paper rather than a thesis on the subject, we make no attempt to provide a rigorous economic analysis that takes into account the life of the products, discounting factors, residual values, penetration rates, and such. Instead, we have projected what the impact would be for a specific one-year period, if the substitution took place at a reasonable level. The year selected is 1988. Selecting a past year removes the uncertainty of guessing what the future may bring and allows us to base our analysis on hard, supportable data. Of course, the results from this analysis can be used to estimate the impact at some future date.

The transportation activities that are studied in this paper are, as mentioned earlier:

- Commuting to work, substituted by "telecommuting"
- Shopping, substituted by "teleshopping"
- Business trips, substituted by "teleconferencing"
- Transportation of information, substituted by electronic information transfer

1. DESCRIPTION OF SUBSTITUTION ACTIVITIES

The four substitution activities under investigation are:

- Work at home (telecommuting)
- Shop at home (teleshopping)
- Teleconferencing
- Electronic transportation of information

1.1 Telecommuting

Of all the substitution activities we studied, telecommuting has received by far the most attention. Telecommuting, in the case of a complete substitution, involves the office worker staying home instead of going to an office, all five days of a work week. (The business is conducted by telephone, fax machine, and computer.) There are several variations to this theme, however. The commuters may prefer to work some days at home and visit the office the other days to perform work that requires interaction with co-workers. Also, the idea of shared satellite offices in the suburbs, where workers from several firms go to perform work away from their main offices, has also undergone trials and received a great deal of attention.

1.2 Teleconferencing

Teleconferencing offers the ability to conduct a business meeting between people located in different places without their having to travel to a common site.

In today's version of teleconferencing, the participants gather in specially equipped rooms at a designated time. (Some firms have teleconferencing rooms at each major location. Alternatively, such rooms can be rented from telecommunications firms such as Sprint.) From there, business is conducted using large television screens and fax machines.

1.3 Teleshopping

Many people already shop at home. The proliferation of catalog shopping has reduced the need to go to a store. Also, cable TV in the U.S. allows access to channels devoted to home shoppers. Nonetheless, a vast majority of Americans still undertake shopping trips that can be substituted by advanced telecommunications services. To differentiate themselves from the current options, these services will need to be a great deal more interactive in nature. The shoppers should essentially be able to see on their televisions the aisles of the selected store, zoom in to see the products of interest, do comparative evaluation of various brands, make their selections, and have the products delivered, with the amount of purchase automatically charged to their specified credit or debit accounts.

1.4 Electronic Transportation of Information

A great deal of information is transported in paper form. There are various ways in which this activity can be viewed. One way is to consider the originator and receiver of information: business to business (e.g., letters, documents), business to individual (e.g., bills, "junk mail"), individual to business (e.g., payments), individual to individual (e.g., letters).

Another way of looking at the information transportation is to consider the time sensitivity of information. We now have regular mail, overnight delivery, and instant delivery (e.g., facsimile, or fax).

While considering substitution potential, we would primarily consider the business-to-business information transportation (specifically, the time-sensitive material). Telecommunications offers an easy way to transfer large volumes of information, which will save the costs associated with the physical transportation of these documents by plane or truck. The fax, of course, provides a part of the solution, but it is not very effective in handling large volumes of information. Eventually, of course, the interactions with individuals or among individuals could also be substituted electronically.

To summarize, telecommunications can substitute a variety of transportation activities. The method used to quantify the benefits associated with substitution is described next.

2. METHODOLOGY FOR IMPACT EVALUATION

The benefits are divided into two categories, the primary benefits and the secondary benefits. The primary benefits are those that are obtained directly as a result of the substitution of transportation by telecommunications, while the secondary benefits are indirect in nature.

The primary benefits considered in the study are:

- Gain in productivity due to a more productive use of the time otherwise spent in traveling
- Energy savings
- Reduction in pollution
- Reduction in transportation infrastructure maintenance cost due to its reduced usage

Note that not having to build additional infrastructure is not considered as a benefit of substitution. It is only one of the options to reduce the transportation problems. Examples of the secondary benefits include:

- Reduced congestion because of many commuters are working at home, which consequently leads to increased productivity of those that continue to commute
- Reduced number of accidents
- Reduced retail inventory because of consumers shopping from home
- Reduced office space requirements
- Reduced retail space requirement
- Reduced paper requirements, leading to the saving of trees
- Reduced need for vehicles, leading to savings in raw materials and freeing up skilled labor so it can contribute to some other industrial sector

Of these secondary benefits, we have quantified and included in the model only the first secondary benefit (i.e., the one dealing with congestion reduction). The estimates of the four primary and one secondary benefits are based on estimated reductions in vehicle-miles, vehicle-hours, and person-hours spent in travel. These reduction estimates, in turn, are derived from expected changes in transportation demand if a certain percentage of trips required for commuting, shopping, or business is substituted by telecommunications and a certain fraction of information is transported electronically instead of in paper form.

The quantification method is fairly straightforward, with the exception of several points that are briefly discussed below.

2.1 Urban vs. Rural Areas

It became very clear in the early stages of research that the benefits attributable to the urban areas differ from those of the rural areas. Not only do the urban areas suffer much more from transportation problems such as congestion and pollution, but also the characteristics of the people affected by substitution are different in the two types of

areas. We, therefore, calculated the benefits for the urban and the rural areas separately, and then added the results to obtain the total benefits.

2.2 Substitution Coefficient

We refer to the fraction of eligible trips that are substituted by telecommunications as substitution coefficient for that activity. (Note: commuting trips by people that are not information workers are non-eligible for substitution.) The table below shows the substitution coefficients we assumed, based on a variety of sources:

Substitution Activity	Substitution Coefficient	
	Urban	Rural
Telecommuting (Information Workers Only)	12%	6%
Teleconferencing		
• Company business	23%	23%
• Non-company meeting	13%	13%
• Conference	0	0
• Training	13%	13%
• Other	0	0
Teleshopping	20%	20%
Electronic Info. Transfer	20%	N.A.

2.3 Congestion

We estimated benefits due to congestion in the following manner:

- We assumed that the level of congestion (measured in terms of vehicle-hours lost) is related to the number of commuting cars
- We then obtained estimates of congestion (past and projected) as well as the number of commuter cars from the literature corresponding to those levels of congestion
- Next, we estimated the slope of the congestion versus the number of commuter cars in 1988, our base case year
- Knowing the reduction in the number of commuter cars due to substitution and the resulting slope, we then calculated the reduction in congestion in terms of vehicle-hours saved.

The time savings for people who are still commuting can be obtained simply by multiplying the vehicle-hours saved by the average number of commuters per car, while the energy and pollution benefits are derived from vehicle-hours saved.

2.4 Productivity Benefits

Converting the time saved into a productivity estimate requires assigning a value to a person's time. It can be argued that the time saved in not having to travel will be used productivity for the benefit of the society. Alternatively, the time saved will add to the leisure time that increases the quality of life, and may also contribute to growth of the leisure industry. Here is how we treated the subject:

- We assumed that the shopping time saved will not lead to productivity benefits, but will instead lead to an increase in leisure time.
- The business time saved was assumed to be productive, with a value approximately equal to that of the average hourly wage
- The value of the commuter time saved because of not having to travel to work, as well as from the congestion reduction, was assumed to be the same figure which the highway community (e.g., The Federal Highway Administration (FHWA)) uses while calculating costs and benefits of highway improvements.

The last assumption, although supportable as accepted practice, can be questioned. Specifically, it is not clear how a few minutes saved in commuting due to congestion reduction can be productively employed. Also, the commuter time most often comes out of the personal time of the commuter, and there is no guarantee that time saved in not having to commute will be used to do productive work. To take these apprehensions into account, we considered a scenario where the value of time saved due to congestion is zero. In addition, to err on the conservative side, we assumed that the value of time saved due to elimination of commuting is also zero. The results of this scenario are shown later and provide a lower bound to the benefit estimates.

2.5 Energy Benefits

This benefit was relatively easy to quantify. The estimates of reduction in vehicle-miles (vehicle-hours in case of congestion reduction) were converted to gallons of fuel saved by calculating the average miles per gallon for a car, a truck, and a commercial plane. These were then converted to dollar savings using the average fuel price.

The effect of reduced congestion was taken into account by making a simplifying assumption that the congestion causes a car to sit idle in traffic. In reality, the car will spend time idling as well as going slowly when congestion is encountered.

2.6 Pollution Benefits

The principal pollutants created by cars, planes, and trucks are carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HC), and particulates (PA). We estimated total reduction in the annual generation of the last four pollutants by means of substitution.

Carbon dioxide was not included because it is yet an unregulated pollutant and therefore the benefits of its elimination are difficult to quantify. We used average value of removing each pollutant from the environment in order to quantify the benefits.

2.7 Infrastructure Maintenance Benefit

We assumed that trucks cause all road infrastructure damage. (It is believed that a 80,000 lb. truck causes as much damage as about 9,000 cars.) Next, we divided the variable cost of highway and airport maintenance by appropriate vehicle-miles to arrive at maintenance cost rates which were then used to obtain infrastructure maintenance benefits of substitution.

3. BENEFIT ESTIMATES

Using the approach outlined in Section 2 and a large number of data sources, we estimated annual societal benefits from a national (U.S.) acceptance of substitution at a reasonable level. A spreadsheet program ("COMTRANS") was developed for this purpose.

As shown in Figure 1, the benefits amount to about $23.2 billion, with the urban areas getting the lion's share of the benefit.

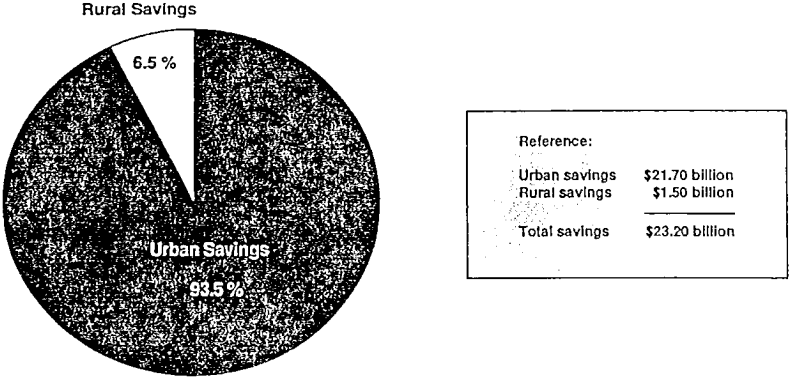
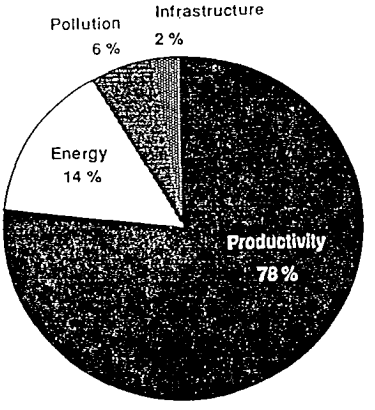


Figure 1: Estimated Annual Societal Benefits of Substitution (1988 Dollars)

In the urban areas, productivity increases amount to about 78% of the benefits, or $16.90 billion, while energy savings represent about $3.08 billion or 14% of the total.

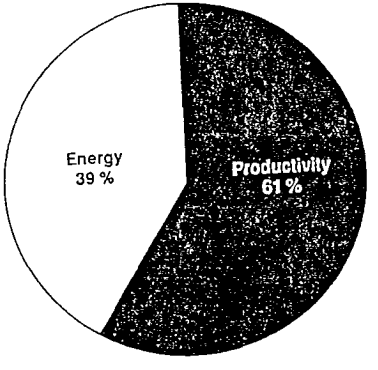
Pollution reduction due to substitution results in a savings of about $1.23 billion (about 6% of the total), while the infrastructure maintenance will be reduced by about half a billion dollars (about 2% of the total). Figure 2 shows this graphically.



Reference:	
Productivity savings	$16.90 billion
Energy savings	$3.08 billion
Pollution savings	$1.23 billion
Infrastructure savings	$0.49 billion
Total urban savings	$21.70 billion

Figure 2: Estimated Annual Savings in Urban Areas (1988 Dollars)

In the rural areas, the productivity gain is significant but not as overpowering as that of the urban areas, as shown in Figure 3. The pie is divided into productivity savings (around 61%) and energy (39%). (We assumed that all the infrastructure savings go to the urban areas and that the reduction in pollution will not result in monetary savings in the rural areas.)



Reference:	
Productivity savings	$0.92 billion
Energy savings	$0.58 billion
Pollution savings	$0
Infrastructure savings	$0
Total rural savings	$1.50 billion

Figure 3: Estimated Annual Savings in Rural Areas (1988 Dollars)

The above discussion does not take into account many other secondary benefits. For example:

- The current retail inventory in the U.S. is about $250 billion. If a 20% substitution in shopping trips results in even a 10% reduction in inventory, the reduction in a dollar amount will be $25 billion, with the annual carrying cost savings worth maybe $2 to 3 billion (assume similar values for 1988).
- The retail floor space in the U.S. in 1988 was about 14.5 square feet per capita, or about 3.5 billion square feet. Once again, a 10% reduction due to a 20% substitution would lead to some 350 million square feet of available space.
- The number of accidents is likely to reduce. This could be a substantial benefit

These give us some idea of the scale of other secondary savings achievable due to a likely level of substitution.

One major assumption in the analysis presented in this paper is that the time saved due to elimination of commuter trips and congestion reduction will be used as productive labor. If this is not the case, the annual benefits drop drastically, from $23.2 billion to $7.1 billion. However, additional leisure time will provide a boost to the leisure industry, reduce health costs and add to the general quality of life. None of these benefits are included in our analysis.

4. COMPARISON TO OTHER OPTIONS

Several transportation initiatives are currently being discussed by the U.S. government and private industry. These include: Intelligent Vehicle Highway Systems (IVHS), alternative fuels, high-speed rail (HSR), magnetic levitation trains (Maglev), tiltrotor aircraft, and advanced air traffic control systems.

We evaluated the implementation costs and benefits of three of these initiatives with those for substitution of transportation by telecommunication. We were careful in using a consistent methodology in evaluating the benefits of each. Figure 4 shows the results of this analysis.

The arrows represent possible ranges of benefits and costs, while the small circle on the arrows indicate the benefits and costs for estimated levels of implementation or adoption. The dotted line for the substitution option is intended to indicate that some level of benefit can be achieved by incremental enhancements to the existing network.

In arriving at the $300 billion implementation cost for the substitution option to be realized, we assumed that a nationwide switched broad-based network using fibre optics will be needed. (One can argue that the equipment already exists for some level of substitution to take place. However, to achieve a significant level of substitution, equipment and network with more capabilities and "pizzazz" will be needed). From various studies, we arrived at the figure of $200 billion for a nationwide implementation of network and another $100 billion for equipment that users will need to purchase.

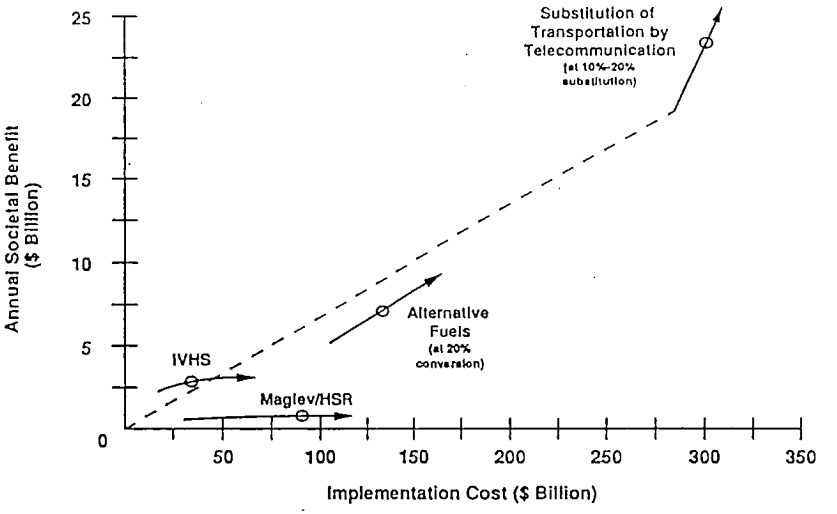


Figure 4: A Comparison of Benefits vs. Implementation Costs of Various Alternatives

Source: ADL Data

5. CONCLUSIONS AND RECOMMENDATIONS

In this paper, we have attempted to quantify the societal benefits of performing by telecommunications certain activities that currently include the use of transportation. The objective of this work is to determine if this type of substitution of transportation by telecommunications will address some major transportation problems, such as congestion, wear and tear of infrastructure, excessive consumption of time, people and energy, and emission of pollutants.

Using reasonable estimates for the percentage of the transportation activities substituted by telecommunications, we determine the annual societal benefits for the U.S. to be on the order of $23 billion, with the urban areas getting the vast majority (93%) of the benefits. In terms of other units, we estimate savings of 1.8 million tons of regulated pollutants, 3.5 billion gallons of gasoline, and 3.1 billion personal hours.

We found these savings compare very favorably with the societal benefits that can be achieved by the other alternatives being considered to address transportation problems, such as the IVHS, Maglev and other high-speed trains, and the alternative fuels (methanol and CNG).

These benefits are likely to be conservative, since secondary benefits, such as savings in retail inventory and retail space due to fewer people visiting retail stores have not been taken into account. Also, the telecommunications infrastructure will be able to support a much higher level of substitution than the 10% to 20% level assumed in this analysis. Thus, if substitution activities are encouraged by national interest or governmental support, the benefit levels could go substantially higher.

The recommendations for future work include:

- Applying the same methodology to evaluate in other countries the potential of telecommunications solving transportation problems
- Performing additional work to determine more accurately the value of time saved due to work at home and shop at home
- Evaluating the issue of pollution reduction on an ongoing basis—any changes in regulations governing the allowable CO_2, CO, NO_x, HC, or PA will affect benefit estimates, most likely by increasing them substantially.

In closing, the entire field of substituting transportation by telecommunications deserves to receive a great deal more attention than it has received in the past. In addition to providing more efficient communication services, it may also be a substantial cure for our transportation woes as well—a cure that has been substantially, and regrettably, overlooked.

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