A paradigm is introduced that demonstrates the difficulty of promoting land use patterns that reduce travel in metropolitan areas. The paper also describes the increasing costs of urban congestion because of individuals who make travel decisions without confronting the full costs of their individual choice behavior. These costs cannot be avoided in today's complex economic system, and manifest themselves as reductions in the quality of life and in the value of massive private investments in real estate. The paper provides a taxonomy of transportation options organized around the production of more information to travelers on the actual costs of their travel in real time, information satisfying final demands, as well as capacity increases to help ensure the efficiency of future urban transportation systems. A list of research needs is developed to help the U.S. Department of Transportation develop a research agenda for analyzing transportation options in terms of their full range of impacts on urban form and their environmental and other external or social costs that individuals do not internalize and account for in their travel decisions. The research needs follow closely the topics and paradigms developed in the paper.
BASIC UNDERSTANDINGS AND BACKGROUND

Interaction Between Transportation and Urban Form

A paradigm shift is needed in the way the interaction between transportation and urban form is viewed. In heartfelt planning goal statements this interaction continues to be viewed in terms of an incomplete model of travel and land use location behavior. This occurs when the hopeful question, Are there land use patterns that reduce urban travel? keeps being asked. This question has not been answered in the affirmative on a metropolitan-wide scale because the relationship is not directly causal. There is a third variable driving them both, namely, the behavior of individuals that affects the demand both for land use and travel.

The question, Are there land use patterns that reduce travel? exemplifies the prevailing "partial equilibrium" model of travel demand. In this model, travel, whether predicted with the Urban Transportation Planning System (UTPS) or a "direct demand" model, is considered to be conditional upon a fixed land use pattern. Land use patterns, of course, are not fixed. It would be desirable to have the research and planning budgets to develop long-run "general equilibrium" models that would enable the prediction of land use and travel simultaneously as these are determined by a given transportation system and by the many other determining factors so eloquently stated in other papers at this conference.

The suggested new paradigm for how the interaction between transportation and land use is viewed is shown in Figure 1. It is based on the behavior of individuals, the bad guys to whom Schulz referred in his keynote address to this conference—incorrigible in their habits, but generally predictably so. Quoting Schulz:

I believe that those of us concerned with transportation in urban America can no longer wait for people to start to behave as we'd like them to: living in compact, high-density residential development patterns; traveling short distances to work along well-defined corridors to destinations in orderly, compact business districts; using public transit in large numbers because they want to, not because they have to; planning their nonwork travel in orderly and efficient ways; and being very socially conscious in their selection and very limited personal use of an automobile. We have to recognize the reality that people are very unlikely to accept, and are in fact likely to strongly resist, significant changes of this sort, especially if they perceive that such changes are limiting their personal freedom of choice.
Referring to the paradigm in Figure 1, the individual to whom Schulz refers has information about a set of opportunities to engage in activities at various locations, some or all of which may involve travel. The individual also has needs—to work, shop, play, be safe, and have a home. These clearly condition how the individual chooses among various activity opportunities involving travel. The individual also has resources (e.g., time and money) that affect response to opportunities to travel and location of activities at various places and prices.

The lack of a direct causal relationship between land use and travel is shown in Figure 1. As mentioned earlier, there is a third variable driving them both, namely individuals responding to opportunities, needs, and resources to "consume" both land and travel. Empirically, the presence of the third variable has been amply demonstrated, causing individuals to consume both more land and more travel as their income increases. In her paper at this conference, Deakin states, "If, as is usually the case, transportation is cheap relative to housing and one can buy more house per dollar farther from the center, households will have an incentive to live farther away from their workplaces."

For better or worse, major investments in highways in the 1950s and 1960s, successful in enabling increased labor productivity and economic development, have sown some of the seeds of their own failure, as is so often the case in an economic system as complex as that of the United States. Success in increasing real incomes in society through transportation and other economic investments has
resulted in increased demand for housing to improve the standard of living. The well-known result of this is that higher real incomes lead urban populations to move farther out from the city centers because more housing can be consumed on more land, as well as more travel at a lower total cost. Until now, the added utility of cheaper land, housing, and a pleasant environment farther from the city centers has been greater for the more affluent urban population than the added disutility of the transportation cost of traveling to and from dispersed housing, employment, shopping, and so forth.

The paradigm in Figure 1 shows that any attempt to reduce travel involves influencing individuals to reduce their consumption of both land and transportation. New high-density developments with possible associated lower travel requirements may appeal to a portion of the urban population, but will they change the overall travel requirements of the metropolitan-wide marketplace?

The paradigm in Figure 1 also suggests that efforts to promote higher-density developments may be appealing only to a relatively small segment of the market that prefers high-density development and walking or traveling short distances to work. This may be only one tail of the distribution of individual behavior as it reveals its preference for housing and employment locations. It may be a mistake to think that an entire distribution of individual behavior can be changed by catering to particular market niches. Indeed, high-density developments must not be made so difficult for travelers that they are not marketable at all.

Finally, the paradigm in Figure 1 suggests that additional measures costing real money are needed to promote certain land uses as an effective way to reduce total vehicle or person trips in urban areas. One type of measure would hit the individual in the pocketbook as a means of inducing him or her to live and travel at lower total social costs. This means internalizing some costs that are not now paid by the individual. Alternatively, taxpayers would pay to provide socially efficient housing and employment choices at lower than private market costs. Absent these stick-and-carrot approaches, simply requiring new developments to be designed to reduce travel may not change the overall distribution of individual behavior in a way that reduces total travel.

Costs of Congestion

Until recently, the transportation cost of adopting and maintaining an affluent land use and transportation-consuming suburban life-style
was low. Fuel was, and remains, relatively cheap, and the fuel taxes levied to build and maintain the transportation infrastructure are only about 10 percent of the total internalized cost of the national automobile-truck-highway-transit system. Fuel taxes are presumed to be an even lower percentage of the total social cost of the transportation system.

But the era of cheap transportation may be coming to an end. As real income has been increased through real labor productivity increases over the last few decades in the United States, a life-style has developed that involves consuming increasing amounts of transportation. Thirty-three percent more trips per person were taken in 1983 than in 1969 (2, p. 2). Preliminary results from the 1990 Nationwide Personal Transportation Study data indicate that trip lengths in urban areas that had remained relatively constant in miles between 1969 and 1983 appear to have increased by 10 to 15 percent over their 1970 to 1980 levels (3). In addition, large metropolitan areas now contain many more people. Ninety percent of the entire population growth of the United States in the last decade (1980 to 1990) occurred in metropolitan areas of more than 1 million people. For the first time, a majority of Americans (50.2 percent) now live in these large metropolitan areas, compared with 45.9 percent in 1980 (4).

It has been said that congestion is the price we pay for free movement. Unfortunately, the free ride may be coming to an end. The capacity of highways in metropolitan areas is quite finite. As the organizers of this conference have stated, current post-Interstate planning “shows a rather grim outlook for highway performance in our major metropolitan areas over the next several decades.”

The automobile-highway system is a classic example of a system that puts private interests over the public interest and is characterized by individual choice. Every time a person drives his or her car onto a congested roadway, far more aggregate delay is imposed on others—on the system—than on the driver. This aggregate delay on others results, in turn, in far more air pollution and energy consumption by others than by the individual causing the delay and pollution in the first place. In economic terms, the marginal private cost of highway travel is much lower than the marginal social cost of travel on the already congested highway system. In fact, the more congested the highway corridor, the greater the difference between the marginal social and marginal private costs of making a trip by automobile.

This result is shown in Figure 2. $V_0$, where the demand curve and the marginal private cost curve intersect, represents the use of the highway under the present circumstances, where the automobile
user pays only the private costs of travel. The societally "efficient" amount of highway use, \( V_1 \), is at the intersection of the marginal social cost curve and the demand curve. The shaded area \( E \), the difference between the marginal social cost curve and the current demand curve, represents the total loss to society from the individual's not perceiving and paying the full societal resource cost of a trip.

This loss to society, or "efficiency" loss, can be explained as follows. If the price of a good were to be less than the marginal cost of producing it, then it would be efficient to produce less of the good. Prices below marginal costs indicate that people are not willing to pay enough for the good to justify what the economy has to sacrifice (the marginal cost) to produce the good. If less were produced, then the value people give up by not consuming the good would be less than the value of the resources saved by not producing the good, and economic efficiency would increase if production were curtailed.

In order to examine options for maintaining urban mobility in the future that will ensure the efficiency of future urban transportation systems, consideration must be given to the congestion costs, which are the delays imposed on others when the individual does not pay the total resource cost of travel. These, in turn, contribute to the other components of the total social costs of added travel included in Figure 2.
Impacts on Land Use

Congestion is the price the system imposes as a result of individual private decisions to locate in sprawling regions and on larger plots of land, farther away from work and shopping. And as increasing amounts of money are spent on housing, the transportation price that individual life-style decisions impose on everyone else is not known by the individual when he or she makes those decisions. Investments are made by individuals in expensive housing without consideration of the total cost of their location decisions. This leads to real inefficiencies; the system has lost its ability to confront consumers with the real costs of their decisions. This is as true in the long run for land use location decisions that generate congestion as it is in the short run for individual travel decisions.

Cheap transportation enabled adoption of a suburban life-style, but transportation is no longer cheap. Congestion is becoming such a problem in metropolitan areas that it leads to a sense of disconnection and threatens the value of the recent massive increase in private investment in suburban and exurban housing and land. In the 1940s, 20 percent of income, on average, was devoted to housing. In the 1980s, this percentage rose to 40 percent (5, p. 202).

In the past 40 years, a life-style has evolved that involves spending much more, in both relative and absolute terms, on land and housing in the suburbs. Investing in real estate—individual home ownership—has been a very good investment. How long can this good fortune be expected to continue?

Meanwhile, public expenditures on highways have been cut in half as a percent of the gross national product since 1960 (6, p. 481). Much more private money is being spent on housing and much less public money on transportation. How long can this disparity in spending be expected to continue without destroying the value of real estate?

At the same time, congestion has increased to the point at which it is out of control, because individuals perceive only a fraction of the total congestion they cause. The capacity of the transportation infrastructure has not been increased to lower the levels of congestion (this would bring the marginal private and social cost curves in Figure 2 closer together), nor is it politically feasible to do so in many major cities. Adding capacity would at least have the effect of internalizing a larger fraction of the costs of travel decisions. In addition, there are so many more people in metropolitan areas that the demand curve in Figure 2 is shifting to the right, and the private and social costs of travel and location decisions are increasing and diverging.
In summary, transportation is no longer so cheap relative to housing. Referring to Figure 1, the cost of the combined land use–travel consumption package is increasing in a way that threatens to reduce the value of housing investments and the amenities of a suburban life-style. As in so many other sectors of a free market society, there is no free lunch. The axiom is "You pay now, or you pay later." The social and environmental costs of congestion are not being paid now by individuals when they make their decisions to consume land and travel (Figure 1). If the urban transportation congestion problem is not addressed systematically with the options presented in the next section, we will pay later, as housing values and quality of life diminish with increasing congestion.

OPTIONS

This paper examines options for maintaining urban mobility in the future that will ensure the efficiency of future urban transportation systems. In doing this, a much larger variety of transportation options is available than was a decade ago. The incrementalism of the 1980s—"make no large plans"—seems to be at an end. Many of the options now involve new technologies and communications and may sound futuristic to some. Although it is hoped that they will be available soon, the time horizon for influencing urban form in coordination with transportation plans is also long.

The old saying "If we don’t know where we’re going, all roads lead there" could not be more true in this context. It is necessary to take a long view in regard to time and technology development to ensure success in this exciting undertaking.

Classes of Options

Figure 3 shows seven classes of options for providing future mobility, with an emphasis on land use–transportation coordination. These are

1. Providing up-to-date information to travelers on their real costs of travel,
2. Providing up-to-date information to transportation providers and institutions on the performance of their systems,
3. Providing conventional highway and transit system capacity increases,
4. Providing technology improvements that offer higher speeds and closer vehicle spacings,
5. Pricing transportation facilities en route and at trip ends,
6. Creating telecommunications options that can satisfy final demands (economic and social activities) where they require less or no travel, and
7. Creating regulatory actions and/or economic incentives that reduce the travel requirements of new or existing land uses.

Each of these classes of options holds considerable promise for helping ensure the efficiency of future urban transportation systems.

Travel Information

Without adding capacity, advanced traveler information systems (ATIS) can allow people to make informed choices to avoid congestion. The adjustments they make can involve changes in travel routes, mode, and destination or a decision to make the trip at a different time or not at all. These new traveler information systems will change the nature of the demand for travel by enabling travelers to know in advance and to control the levels of congestion at which they will travel individually. Ultimately, these traveler information systems may have a long-run dimension, forecasting travel conditions not only a half-hour in the future for short-run travel choices but also 5 years into the future for land use and activity location decisions.

Figure 1 suggests that such systems may have a profound effect on both land and travel consumption in metropolitan regions. Opportunities for activity at various locations are only as relevant as the information available about them and about the conditions of travel to reach those locations. This means that new traveler information systems will provide benefits as a result of the information they give to travelers on their expected trip times and costs, in addition to the benefits they give from shortening trip times. Simple technological calculations of increases in capacity with intelligent transportation systems will not provide a good description of the benefits. The benefits from such systems will come as much or more from user interactions with the system as from increases in effective network capacity supplied through short-term operational improvements to these systems. Nevertheless, the latter will certainly be an important result of an improved transportation information environment. Indeed, they are the second class of options that it is necessary to consider, as shown in Figure 3.
Information for Managing System Operation

The short-term system operational improvements that result from improved information on system performance and travel behavior will greatly benefit public and private transportation providers in their ability to manage the available system capacity in real time. Advanced traffic control systems will be able to respond more intelligently and make more efficient use of available highway network capacity. They will even be able to change the modes of transportation options offered [e.g., by setting up high-occupancy-vehicle (HOV) and transit options as warranted by conditions such as major accidents and other incidents that cause the majority of traffic delays].

Capacity Increases

New construction decisions to increase the capacity of current transportation modes will also be made with much more information about their effectiveness. Many needed improvements in the current highway and transit systems have been backlogged by a shortage of money for construction and maintenance. As shown in Figure 3, the most direct impact of this third class of options will be in terms of the
long-run restructuring of the physical transportation system. The new transportation information environment will allow the pinpointing of recurrent bottlenecks causing congestion and accidents and enable the most cost-effective capacity increases to accommodate travel to be made, regardless of mode. There is also considerable interaction between Options 2 and 3, because the capacity increases can provide more flexibility for appropriate short-term system management responses to unusual traffic conditions.

**New Technology**

New technology will not only allow the more efficient construction and operation of conventional modes, it will also provide the fourth set of options in Figure 3, involving higher speeds and closer vehicle spacings. High-speed trains are already operating in Europe and Japan but not in the United States. Introducing higher speeds at the metropolitan scale may have dramatic effects on urban form—even to the extent of tying nearby metropolitan areas together (e.g., Baltimore and Washington). Automatic vehicle control (AVC) systems would provide much closer vehicle spacings and possibly higher speeds that would dramatically increase system capacity. Elements of AVC systems show considerable promise of being introduced in the 1990s to improve automobile driving safety (e.g., vehicle proximity and lane-edge warning devices).

Providing higher ground speeds and capacities is perhaps the easiest of the new technologies to evaluate for impacts on demand and urban form and on congestion and other externalities. In contrast to the uncertainty of evaluating the impacts of improved information, the impacts of this fourth set of options are related to how they change conventional level-of-service measures (travel speeds, times, etc.).

**Pricing**

Some forms of pricing clearly are noncoercive, such as establishing new toll roads at market prices for congestion relief or providing incentives for HOV use (e.g., reduced HOV parking costs). Some forms of pricing may be more controversial, such as building new toll roads with public subsidies and charging vehicles using these roads by their weight, energy efficiency, or air pollution. This would allow pricing at levels that cover some or all of the social costs of driving on these new roads. Also controversial are proposals to tax the free parking employee benefit—or at least make employer transit subsi-
dies tax free. These could help high-density central business districts. Some forms of pricing, such as areawide congestion pricing, are very controversial at the present time. Inevitably, however, pricing will be made much more possible, and very likely much more acceptable, as better information from new transportation technologies provides users and managers with informed choices on using transportation capacity more efficiently while still preserving people's freedom to travel when and where they want.

Telecommunications and Regulation

Ease of analysis does not characterize the sixth and seventh options presented in Figure 3. These are "travel substitution" options that involve changing the location of activities and reducing or even eliminating the travel required to carry out those activities. These options include

- Telecommunication that can satisfy final demands (work, shopping, and recreation activities) at locations requiring little or no travel and
- Trip reduction regulations such as HOV use requirements at employment sites to reduce vehicle trips or requirements for balancing jobs and housing and other housing or employment preference programs to reduce the person-trip requirements of new or existing land uses. These regulations also include more conventional restrictions on parking or on truck loading and unloading at curbs in city centers.

The first of these two options holds out the possibility of intervening in the paradigm in Figure 1 and reversing the positive but spurious correlation between the consumption of land and travel. To the extent that communications can satisfy final demands—economic and social activities at locations requiring less travel—there will be a reduction in the derived demand for travel.

On the other hand, the paradigm in Figure 1 suggests that additional measures costing real money are needed to make the seventh option an effective way to reduce total vehicle or person trips in urban areas. For example, if the costs of high-density developments can be lowered to compete with the lower costs of suburban housing, all else being equal, their cost advantage may help reduce travel. Alternatively, all taxpayers would pay to provide socially efficient housing and employment choices at lower than private market costs. Research on these issues is necessary, as proposed later in this paper.
Option Shifts

This discussion of options shows that there has also been a dramatic shift from 10 years ago in the options that transportation planners can consider to ensure the efficiency of future urban transportation systems. The incrementalism of the 1980s has given way to excitement in the field and many new possibilities.

The reasons for this shift are many. The problems are worse. As noted earlier, 90 percent of the entire population growth of the United States in the last decade (1980–1990) occurred in metropolitan areas of more than 1 million people. Congestion has grown with this population shift and with 10 years of economic boom in the 1980s, resulting in the marginal social cost of added highway travel rising much faster than its marginal private cost. It has also become very difficult to add new transportation capacity on new rights-of-way in most of our largest cities to alleviate this congestion. At the same time, the components of the social cost of congestion—delays imposed on others, air pollution, energy consumption, and housing and income distribution disparities—are moving much higher on the social agenda.

Solutions to these urban transportation problems also seem much more feasible. An explosion of information exists in virtually every facet of daily life. Microchips and consumer electronics have brought us new intelligence. This intelligence, or ability to process large amounts of information for the benefit of individuals, has the potential for great benefit. As yet, road transportation and transit remain relatively unpenetrated by the information revolution that has altered many other aspects of work and leisure. Thus, a new transportation information infrastructure has the potential to dramatically increase the efficiency with which transportation resources are spent by individuals and society.

RESEARCH NEEDS

Research is needed to evaluate options for serving existing travel patterns, controlling demand, improving system performance, and restructuring the transportation network to better meet demand. A list of research needs is presented that relates to the material presented in this paper. This list represents one of several assigned points of departure for the more complete research agenda resulting from the conference.

The list of research needs begins with the premise that demand is not fixed. Transportation capacity is not being increased to accom-
moderate some imagined fixed travel demand, as was the philosophy of
the 1950s "Red Book" (7). Considerable progress has been made in
recognizing and being able to predict how travel varies with its many
long- and short-run determinants. The emphasis of the research
needed now is on coordinating land use and transportation and
understanding the total social costs at which various transportation
options "produce" travel. It is necessary to know and plan for the
many other factors besides transportation that affect land develop-
ment. Better knowledge of the total social costs of travel will en-
able more informed investment decisions in transportation options
and more equitable assessment of the costs of transportation
improvements.

This list of research needs is therefore broken down into two parts:

1. Research about demand (Figure 1) and
2. Research quantifying the total social costs of travel (Figure 2).

Research About Demand

Research needs about demand relating to the paradigm in Figure 1
include the following questions:

- How do individuals react to information and travel conditions
  (costs) in their decisions to consume land and travel?
- How are resources and travel conditions likely to change in the
  future in terms of how these affect individual behavior?
- How are the population of individuals and their needs likely to
  change in the future?

Examples of more specific related research topics include the
following questions:

- Do the new technologies in the list of options in Figure 3 affect
  demand in inherently different ways from currently available modes
  and technologies?
- How much of the recent increase in the percent of our incomes
  devoted to housing (from 20 percent to 40 percent in the past 40
  years) has resulted from increases in interest rates, property taxes,
  utilities, and so forth, and how much is a real increase in price for the
  same or a higher-quality house?
- How have recent increases in urban traffic congestion affected
  the value of privately owned real estate?
• How does constraining parking availability (or other transportation services) below market demands affect the marketability of new urban development projects?
  • Will improved information about travel choices cause travel to increase or decrease?
  • What transportation options (including subsidies) can both improve travel conditions and reduce travel?
    • What are possible strategies for internalizing certain social costs of travel that can be implemented in a politically fair and acceptable manner?
    • How closely will “socially efficient” land use and travel distributions resemble those in today’s cities?
  • How closely will they if “socially efficient” is limited to the costs associated with travel (Figure 2)?

Research Quantifying Total Social Costs of Travel

Research needs relating to the private and social costs of travel (Figure 2) include the following questions:

  • What are the components of the social costs of travel that are related to congestion?
    • Are there major social costs of travel that are inversely related to congestion (e.g., the costs of socially inefficient land use distributions)?
    • What are the values of the components of social costs of travel for different levels of travel and congestion?
    • How do the social costs of travel vary with different strategies for internalizing them in decisions to consume land and travel?

Examples of more specific related research topics include

  • Quantification of the private and social cost curves in Figure 2 for automobile congestion costs only (travel time and delay) for specific cities and travel corridors;
  • Quantification of the relationship between automobile congestion and such externalities as air pollution, traffic accidents, noise pollution, and energy consumption;
  • Determination of the relationship between automobile congestion and land value in U.S. cities;
  • Determination, under current conditions of travel behavior and internalized travel costs, of the reductions in the total social costs of travel from increases in the capacity of conventional modes;
• Determination of whether any of the new technology options in Figure 3 promise significantly greater benefits from equivalent investments than increases in the capacity of currently available modes;
• Determination of what the incidence is of reductions in the social costs of travel from alternative investments and what the resulting implications are for more equitable assessments of the costs of infrastructure improvements;
• Determination of how much of the recent increases in congestion and the related social costs of travel in U.S. cities is caused by increased population density and how much is caused by increased trip lengths for certain segments of the population (e.g., lower-income families seeking cheaper housing on the periphery of metropolitan areas);
• What the benefits are from requiring that only those transportation investments be made whose costs are less than the benefits they provide from reducing the total social costs of travel; and
• Determination of possible loss of long-run benefits from travel if road pricing were used to internalize the social costs of travel.

REFERENCES